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Ralph M. Wheeler

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29 August 1980

Topical Report for Period 1 January 1980—31 July 1980

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Modifications to provide SXTF* capability at either of two candidate sites, the Mark I space chamber at Arnold Engineering Development Center, Tullahoma, Tennessee, and the "A" chamber of the NASA Space Environment Simulation Laboratory, Houston, Texas, are described.

*(Satellite X-ray Test Facility)

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1. INTRODUCTION

The need to provide full-system tests of military satellites to determine their nuclear survivability has led the Defense Nuclear Agency (DNA) to develop a satellite x-ray test facility (SXTF). The purpose of the SXTF is to provide a facility where satellites can be exposed to a spectrum of x rays simulating potential on-orbit nuclear environments.* This test facility was initially proposed as a new facility consisting of a large spherical or cylindrical space simulation chamber with internal dimensions of about 30 m. The proposed facility consists of an integrated plasma radiation and bremsstrahlung x-ray source, and the associated data systems, satellite preparation facilities, and appropriate laboratory and administrative space.

The principal phenomenon being evaluated is the system-generated electromagnetic pulse (SGEMP) created by impinging x rays. Transient radiation effects on electronics (TREE) and spacecraft charging effects can also be evaluated. Since the electromagnetic behavior of the satellite can be substantially affected by connections to the satellite, by secondary electromagnetic reflections from the wall of the vacuum vessel, and by noise pulses coming from other portions of the system, careful attention must be paid in designing the interior of the vessel to ensure the damping of electromagnetic waves and providing sufficient spacing between the satellite extremities and the vessel walls. Other considerations in ensuring that the exposure results represent a real operational condition include the requirements both to retrieve the response data from the satellite and to control the satellite via electrically isolated links rather than by use of hard-wired links. All of these affect the quality of simulation that can be obtained.

1.1 THE REFERENCE DESIGN AND ALTERNATE SITES

The original reference design for the SXTF (Ref. 1) described a proposed facility to be built at Vandenberg Air Force Base. Major program considerations in late 1979, including estimates of initial cost and construction schedules; analysis indicating that a smaller chamber might be acceptable; and the availability of some existing large space simulation chambers, led DNA to restructure the SXTF program. Several alternative facility configurations were evaluated. The principal candidates were:

*Described in a separate, classified report to DNA.

- Construction of a smaller vessel (a 'tee' configuration) at Vandenberg AFB.
- Use of an existing 72-foot (22-m) carbon steel spherical vessel at Arnold Engineering Development Center (AEDC).
- Construction of a tee vessel at AEDC that would use considerable existing pumping equipment and structures.
- Modification of either the NASA/Johnson Space Center, space environment simulation laboratory 'A' chamber, or the Mark I space simulation chamber at AEDC.

Other existing chambers were also considered but were eliminated as candidates for the SXTF due to non-availability. These included the NASA space power simulator at Plumbrook and other wind tunnel pumpdown vessels in use at NASA test facilities at Langley and Moffett.

A definitive engineering design was developed during the last half of 1979 for each of these initial candidate SXTF sites by Norman Engineering Company (NEC), under contract to DNA, to determine the feasibility and estimated costs to construct new facilities or to modify existing candidate sites. The DNA SXTF site selection committee reviewed this information early in 1980 and determined that the NASA 'A' chamber and the AEDC Mark I chamber were the most reasonable candidate locations to pursue. The fundamental factors in this decision were the higher costs and delayed schedule of building any new vacuum vessel and the cost associated with structural problems with the existing 72-foot (22-m) sphere at AEDC.

The choice between the remaining two candidates, the AEDC Mark I and NASA 'A' chambers, is continuing to be evaluated, and depends on four basic considerations:

- The engineering feasibility and construction risks to modify these existing functionally operating space chambers.
- Judgment of the simulation quality that can be achieved in these vessels, which are smaller than the original reference design.
- The operational and administrative arrangements to be shared by DNA and the host site.
- Costs and schedules to modify the existing vessel and structures.

1.2 SXTF CANDIDATES: NASA 'A' CHAMBER AND AEDC MARK I

To develop the information required for a final decision to select the SXTF candidate site, a more detailed engineering plan, showing structural details and revised costs and schedules for both AEDC and NASA, has been undertaken by DNA during the first half of 1980. These plans primarily address the RDT&E element of the program.

The RDT&E (research, development, test, and evaluation) portion of the facility consists of the photon sources, their integration into the existing vessel, and the devices needed to create the proper simulated environment (damper, plasma, electron suppression) and the sensors, instrumentation, data links, and data acquisition/processing needed to support SXTF test operations.

Administrative and laboratory/shop requirements which are not available on site will be added under the MILCON (military construction) portion of the program.

The engineering drawings, structural analysis, and construction required for modification of the candidate vessels, developed by NEC, are contained in a companion document to this description of the two candidate sites (Ref. 2). This report is intended to provide a more general and comprehensive description of the features and equipment proposed for the two candidate sites.

The many requirements and features of the SXTF that are common to both locations and those aspects of the SXTF which are site-unique will be described. The essential features of the originally proposed SXTF are to be included in the site modified to provide SXTF testing. Certain features of the original Vandenberg facility that would provide greater flexibility in terms of changes, additions, or future capability have not been included in the modified sites. The technical support contractors to DNA have coordinated design concepts and requirements with NEC to make optimum use of the existing facility. All have recognized that modifying an existing facility places structural, space, and physical arrangement limitations on the design that would not occur in a new facility.

The AEDC and NASA chambers have similar features. Each is a stainless-steel, high-vacuum, vertical-axis cylindrical space chamber. They have full-coverage cold walls, helium cryogenic pumping, and diffusion pumps. The x-ray sources would be integrated into the tank of either chamber in a similar manner (Ref. 2 describes the structural differences).

Present plans also call for instrumentation and data functions to be added to the existing facility. These functions will be performed from new RF-shielded control and data rooms built into the new structure housing the x-ray sources. The administrative and laboratory functions specified in the original reference design will be provided through the addition of a separate, smaller MILCON structure placed nearby the existing building housing the chamber.

1.3 REPORT ORGANIZATION

Section 1 has provided a brief introduction to the DNA SXTF project as of June 1980. Section 2 is a description of the RDT&E modifications and additions to the facility, with particular emphasis on the requirements and basic concept for the photon sources and the vessel internal subsystems used in performing x-ray tests. Section 3 is a description of instrumentation systems needed for control of environmental subsystems, photon sources, and experiment data. Section 4 addresses the MILCON functions and the general layout of a proposed MILCON structure. Section 5 provides a general summary of the concept of SXTF test operations and the concept for providing physical security and radiation protection needed as a result of x-ray testing.

2. RDT&E DESCRIPTION

2.1 RDT&E PROGRAM MODIFICATIONS TO AEDC AND NASA FACILITIES

This description of the SXTF and a companion set of drawings and technical design data by NEC (Ref. 2) comprise the requirements to which the RDT&E elements of the SXTF are to be developed. Procurement of the photon sources, selection of either AEDC or NASA as the SXTF site, and a final design effort by the selected A&E will be undertaken in FY 1981. This effort will expand and augment the existing design concept into sufficient detail to write an RFP and procurement package for modification of the selected site.

The RDT&E program is structured as follows.

1. The photon sources will be procured under direct contract to DNA. At present, two competitive designs for both the MBS and the PRS are being developed, one by Physics International and one by Maxwell Laboratories, Inc.
2. The designs for the vessel modifications, internal subsystems, instrumentation, and all foundations and structures required for the photon source and supporting environmental and control subsystems are to be developed by the A&E under the direction of DNA. Technical guidance and review of the design concept are being provided by the SXTF community.
3. It is anticipated that the non-source portions of the SXTF will be obtained through a procurement, following the concepts and specifications described in this document and as shown in the design drawings of Reference 2.

A description of each subsystem being integrated into the modified chambers is provided in the remainder of this section. The SXTF subsystems presently included in the modification plan for AEDC and NASA are:

- Test chamber (existing vacuum vessels)
  - -- AEDC Mark I
  - -- NASA "A" chamber

- Photon sources (to be added)
  - -- MBS 200-module array
  - -- PRS machine
- Vacuum subsystem (existing at each site)
  - -- Mechanical roughing pumps
  - -- Cold wall/cryogenic pumps
  - -- Diffusion pump
  - -- Repressurization system
- Electron backscatter control material (to be added)
- EM damper device (to be added)
- Electron beam sources (to be added)
- Geomagnetic field reduction
  - -- NASA (existing)
  - -- AEDC (to be added)
- Solar illumination
  - -- (Partial permanent system at NASA)
  - -- (Existing temporary system at AEDC)

The background of activities and technical concerns about the subsystems are described. Major issues addressed over the past few years relating to the subsystems are described. A complete chronology of events is not provided, nor is any detailed discussion of the physics or phenomena. Additional information on previous SXTF concepts and technical issues is contained in Reference 1.

2.2 VACUUM CHAMBER

The SXTF vacuum vessel provides the basic structure for achieving a simulated space environment. To be integrated physically into the side of the vacuum vessel is the SXTF x-ray source. This source integration requires that one large penetration on the order of 2 m in diameter be added to accept the single large plasma radiator, and that a thick steel source plate (~7 x 7 m), with ~200 13-inch (33-cm) holes, be welded into the side of the vessel to accept the modular bremsstrahlung source. In addition, the vessel houses the spacecraft and experimental environment subsystems (called vessel internals). The test object suspension, the vessel work floor, and the many penetrations for special devices and instrumentation are functional components of the vessel. Presently, two existing vacuum vessels are being considered for the SXTF.

Each of these candidate vessels satisfies the initial requirements in all aspects except size. Many factors were evaluated (Ref. 1) early in the program concerning features of the vacuum vessel, such as the shape and size of the vessel, location of sources and doors, vessel construction material, and test object suspension mechanisms.

The AEDC and NASA vessels appear to be capable of accepting modifications which satisfy SXTF needs. One unique difference between these two candidates sites and the original SXTF reference design is that they are vertical cylinders and require the test object to be suspended vertically rather than horizontally, as originally intended. Examination of this requirement by TRW and GE indicates that vertical suspension techniques can be accomplished.

Satellite access for the AEDC vessel is via the top of the cylinder through a 20-foot (6.2-m) removal hatch. The NASA chamber access is through a 40-foot (12.4-m) hinged door in the side of the chamber.

Various tank materials were initially considered including dielectric, carbon steel, and stainless steel. Investigation of the dielectric tank revealed negative aspects in the high technical risk and the need for an extensive development program, and it was rejected. Carbon steel is less costly than stainless but could fracture when exposed to possible cold wall refrigerant (LN_2) spills, and requires special surfacing to achieve high vacuum. As a result, stainless steel has been specified as the desired vessel material. Both AEDC and NASA tanks are stainless steel.

The tank shape was initially shown as a sphere because of symmetry and cost arguments. Additional shapes were later considered that would maximize the fluence by allowing the test object location to be close to the source while minimizing the perturbation introduced by the tank wall which occurs when the object is moved towards the source in a sphere.

The tank was initially specified to have a 30-m diameter, based primarily on analytical judgment that a 2:1 tank-to-test-object relationship was acceptable for the 14-m reference satellite (FLTSATCOM). Later, calculations of the detailed response of satellite-like objects in tanks (with and without dampers) were performed to further quantify acceptable tank size. These studies have indicated that, although a 30-m vessel is still desired in terms of best simulation quality, smaller non-spherical vessels appear to give acceptable results.

2.2.1 NASA and AEDC Vessel Characteristics and Structural Modifications

Figure 1 is a photograph of the NASA "A" chamber, a cylindrical vessel 65 feet in diameter with an overall height of 117 feet. The vessel has a 40-foot-diameter door on its east side which will be used for spacecraft entry. Table 1 presents a summary of the chamber characteristics. The inside wall of the vessel is covered with a cold wall/cryo panel. The northern wall contains solar illuminators. Both the cryo panels and the solar illuminators have to be modified for SXTF use. There are circumferential stiffeners around the vessel and longitudinal stiffeners along the sides of the vessel. The location selected for source integration to the vacuum vessel has least interference with structural support and the pumps and pipes required for vessel operation.

The structural modifications and the new structures to cover the sources that will be built over the existing pump room are shown in Figure 2. The NASA vessel is depressed about 20 feet below grade. An existing rotatable floor at grade level limits the working volume from grade level to the top of the chamber. The SXTF x-ray sources are installed at mid-height of this working volume.

At NASA, access to the north of the existing building is via the air-lock door and the existing pump room roll-up door (Figure 3). A loading dock needs to be located adjacent to vehicular traffic and still permit loading which will not obstruct street traffic. The loading area must also have access to an oversized freight elevator to the second floor.

The MILCON building houses functions that are not part of the vessel modifications or the construction addition to the existing building but should be nearby and have access to this entrance. A tentative location is immediately north of the new structure, within a short distance of the loading dock.

Figure 4 is a drawing of the AEDC Mark I chamber, a cylindrical vessel 42 feet in diameter with an overall height of 82 feet. This vessel has a 20-foot-diameter opening on top that will be used for spacecraft entry. Table 2 presents a summary of the chamber characteristics. The inside wall of the vessel is covered with cryo panels which have to be modified for SXTF use. It also has circumferential stiffeners along its height. The vessel is surrounded by occupied building levels on three sides. Therefore, only the west elevation offers direct exterior access above and below grade level.

The structural modifications and the new structure to cover the sources are shown in Figure 5. The centerline of the Mark I is essentially at grade level. The SXTF

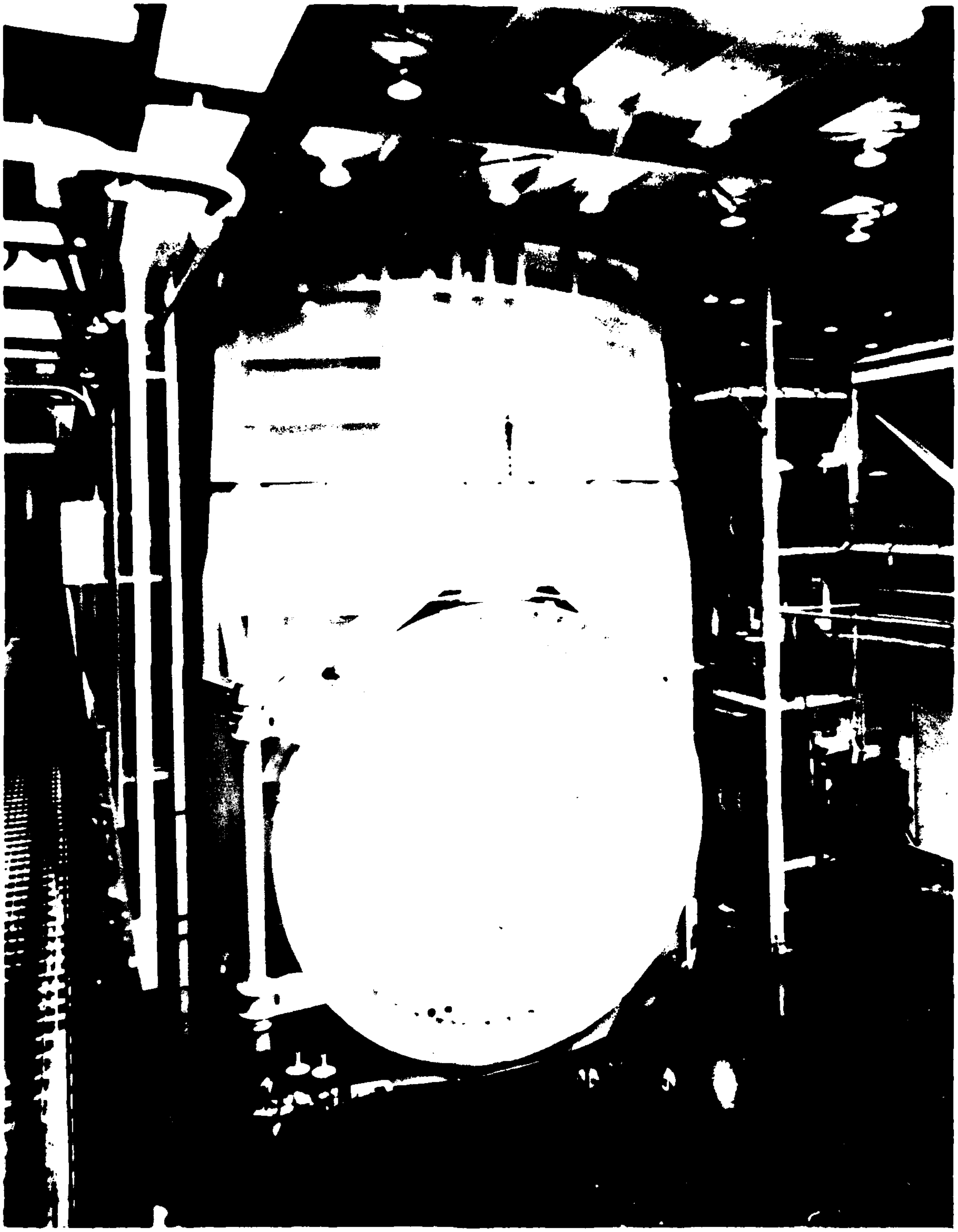


Figure 1. NASA 'A' chamber

Table 1. Characteristics of Existing NASA 'A' Chamber

General Characteristics	
Vessel	Vertical stainless steel cylinder
Outside dimensions	19.8 m (65 ft) diameter by 36.6 m (120 ft) height
Working dimensions	16.8 m (55 ft) diameter by 27.4 m (90 ft) height
Test article weight	68,100 kg (150,000 lb) concentric load maximum
Access	12.2 m (40 ft) diameter side-hinged door
	Dual manlocks at floor and 9.5 m (31 ft) level
Vacuum	10^{-5} torr or lower
	Mechanical pumps, and helium cryovac system
Heat Sink and Special Thermal Simulators	
Full chamber shroud	Subcooled 90-K LN_2 shroud
	330,000 W total heat absorption capacity
	Can be heated to 312°K with GN_2
Wall emissivity	0.95
Special simulators	Solar, albedo, and planetary radiation, as required
Solar Simulation	
Top sun	1 to 19 carbon arc modules producing a 4-m (13 ft) diameter beam maximum
Side sun	1 to 31 xenon modules producing a 4-m (13 ft) by 10-m (33 ft) beam maximum
Decollimation	50-min half angle
Intensity	622 to 1,353 W/m^2 (controllable)

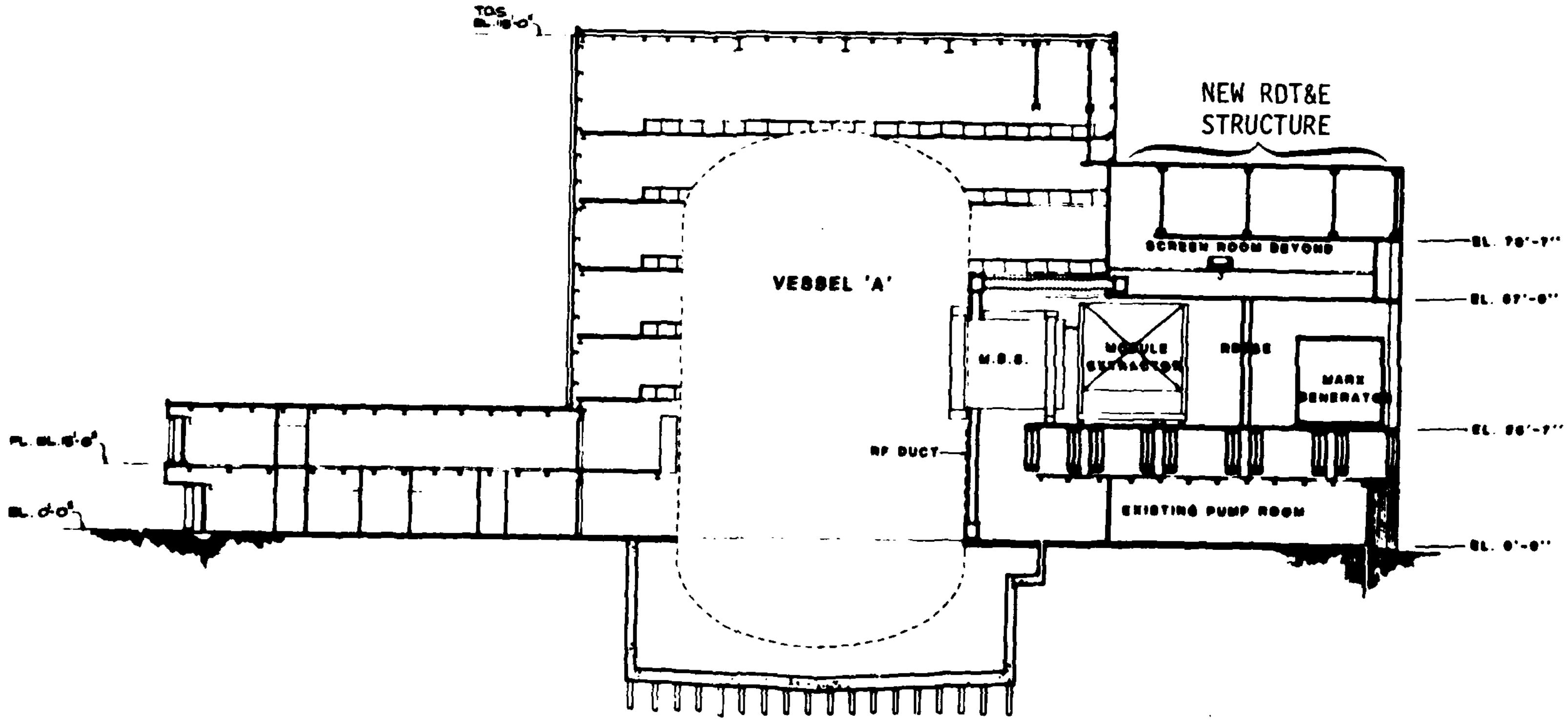


Figure 2. NASA "A" chamber, showing new RDT& E structure

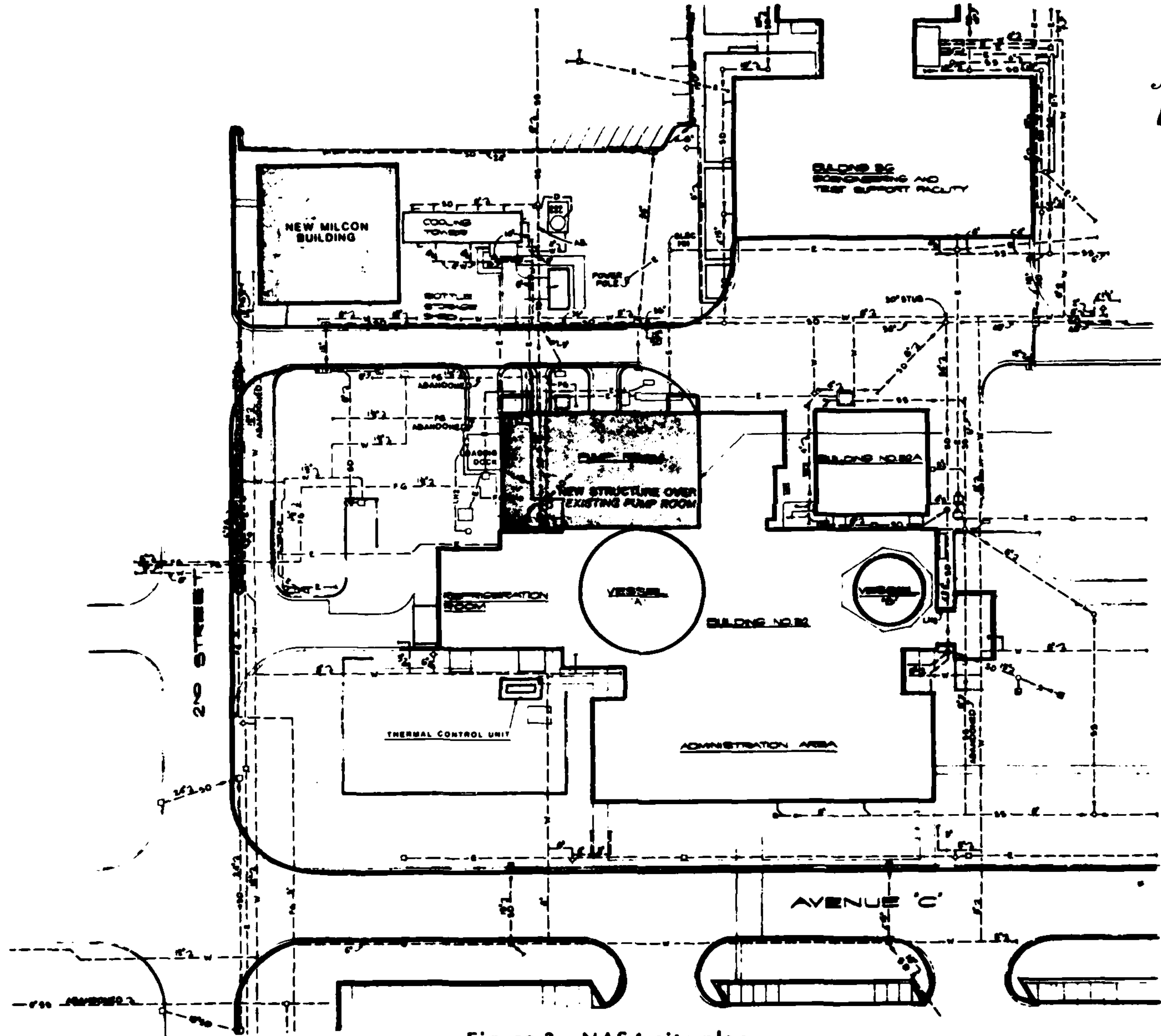


Figure 3. NASA site plan

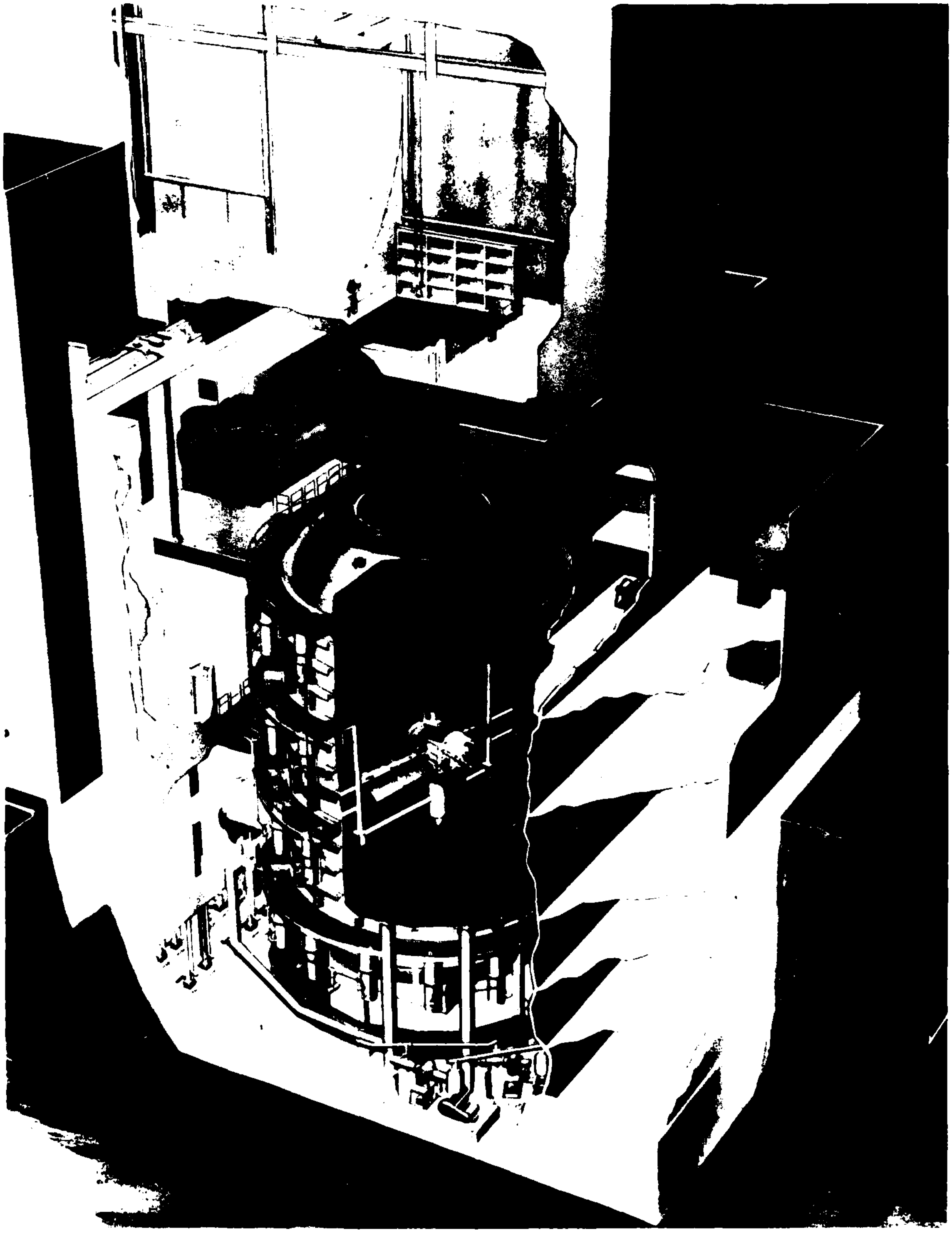
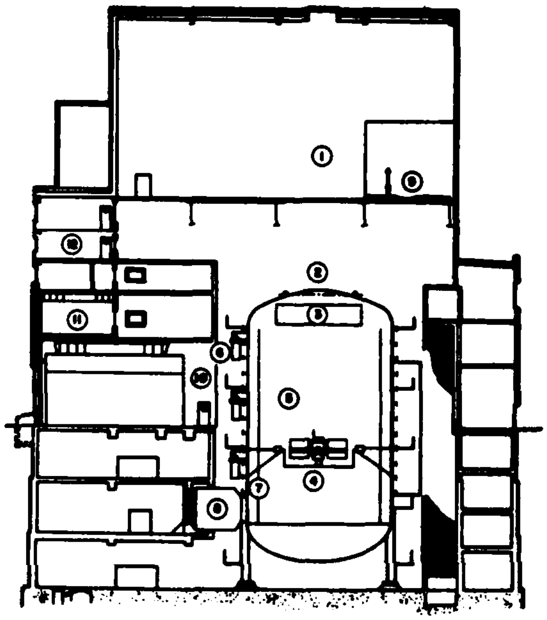


Figure 4. AEDC Mark I chamber

Table 2. Characteristics of Existing AEDC Mark I Chamber

1. Buildup area
2. Main chamber
3. Solar simulator
4. Test article
5. Test article handling system
6. Diffusion pumps
7. Cold wall and cryopumps
8. Access lock
9. Clean room
10. Main building entrance
11. Control room
12. Data acquisition room



- Vacuum chamber size: 42 ft diameter x 82 ft high (outside)
  36 ft diameter x 65 ft high (inside)
- Pressure altitude: Sea level to 300 statute miles (1×10^{-6} torr)
- Thermal radiation simulation: Solar (12 x 18 ft); albedo; earthshine
- Wall temperature: 77°K (-320°F)[a]
- Cryopump temperatures: 22°K (-423°F)[b]; 4°K (-452°F)[c]
- Dynamic simulation: 2-sec zero-G operation
- Plume test capability: Maintain 240,000-ft altitude for engines up to 300-lb thrust and 300,000-ft altitude for engines up to 25-lb thrust

[a]Liquid nitrogen, [b]gaseous helium, [c]liquid helium

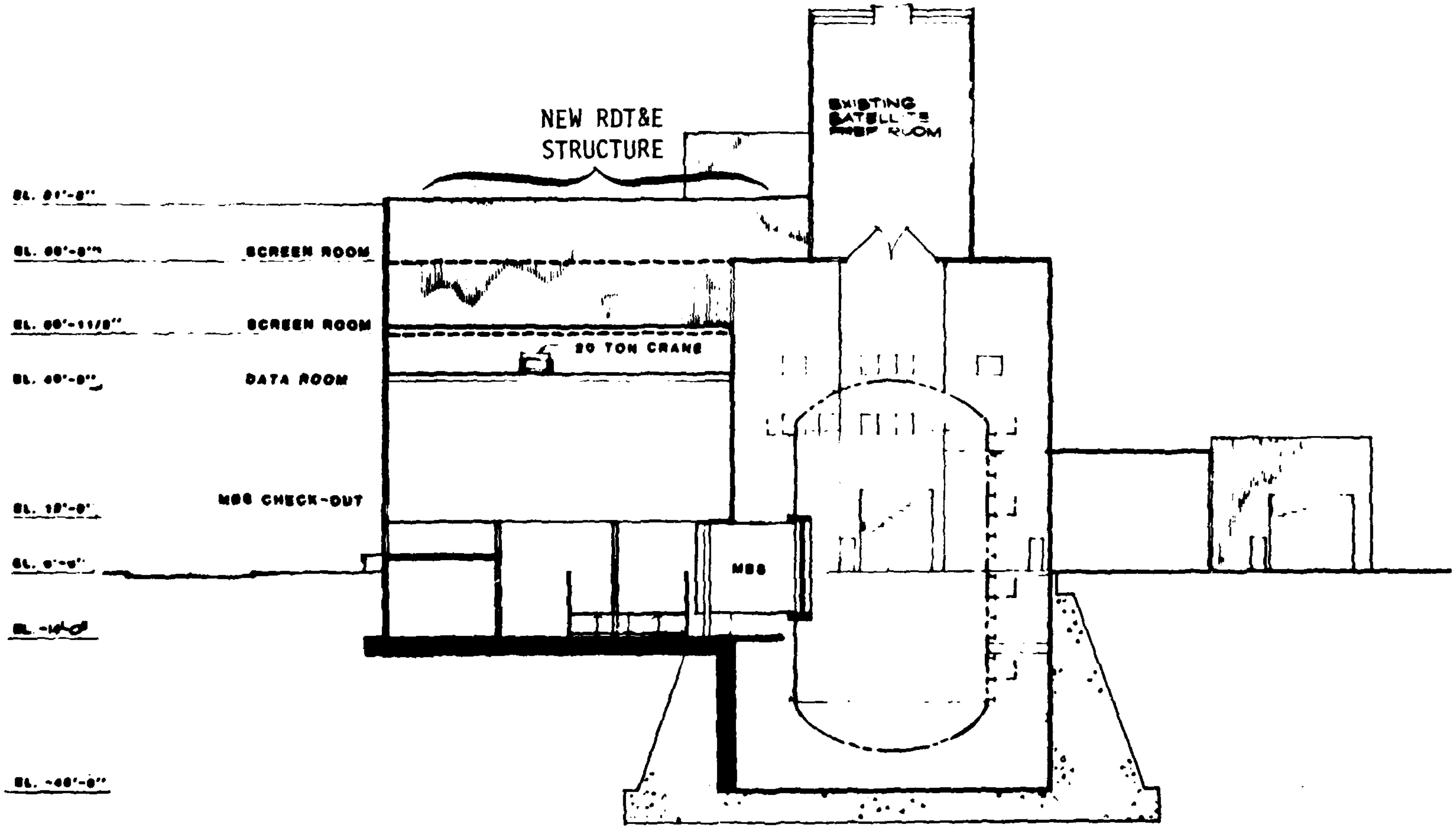


Figure 5. AEDC Mark I chamber, showing new RDT&E structure

sources are placed at this midpoint of the vessel by excavating the SXTF working floor about 15 feet (4.5 m) below grade.

Interference with existing structures and functions is minimal from this direction (Figure 6). The new loading dock is to the west of the facility. Loading activities could interfere with traffic on the roadway running west of the facility, but should not obstruct flow when vehicles are not loading. MILCON functions will primarily flow through the existing access to the north of the Mark I building, thereby requiring no special pedestrian access to the new facility.

2.2.2 Test Object Suspension and Power

The test object support mechanism and the tank floor were included in the original reference vessel design. The major issue relating to these items concerned the test object support weight. The probable weight of a satellite test object has been discussed a number of times, with present spacecraft now reaching loads of 2000 to 4000 lb (909-1819 kg). A limit of 5000 lb (2273 kg) was suggested early in the program, but satellite launches via the space shuttle raise the possible weight to 30,000 lb (13,636 kg). Long-term future space weights have been raised to 100,000 lb (45,455 kg), as suggested by TRW. A more realistic value of 10,000 lb maximum has been established as a design load for the test object hoist, strongback, and satellite suspension mechanism.

The strongback assembly designed for AEDC or NASA is suspended from four crane rail support points which provide for elevation and travel in the direction perpendicular to the vessel's cylindrical axis. The turntable is connected to the strongback through its hub, which houses an electrically driven gear drive capable of vacuum operation. This provides rotational positioning of the spacecraft.

Test object suspension and the arrangement of the photon sources and tank internal subsystems (cold walls, damper, etc.) are shown in Figures 7 and 8.

The hub of the strongback-turntable assembly is used for transition of the fiber optic data link and the spacecraft umbilical cord through the center of the suspension device. The umbilical cord and power plug are lowered to the satellite using gravity and retrieved using a power-operated winch. This attachment design minimizes the load effects on the spacecraft during repositioning.

It is expected that the spacecraft will receive power from an external source during installation, checking, and possible pre- and post-shot operations, with provision for temporary disconnection of the external power connections at the spacecraft and

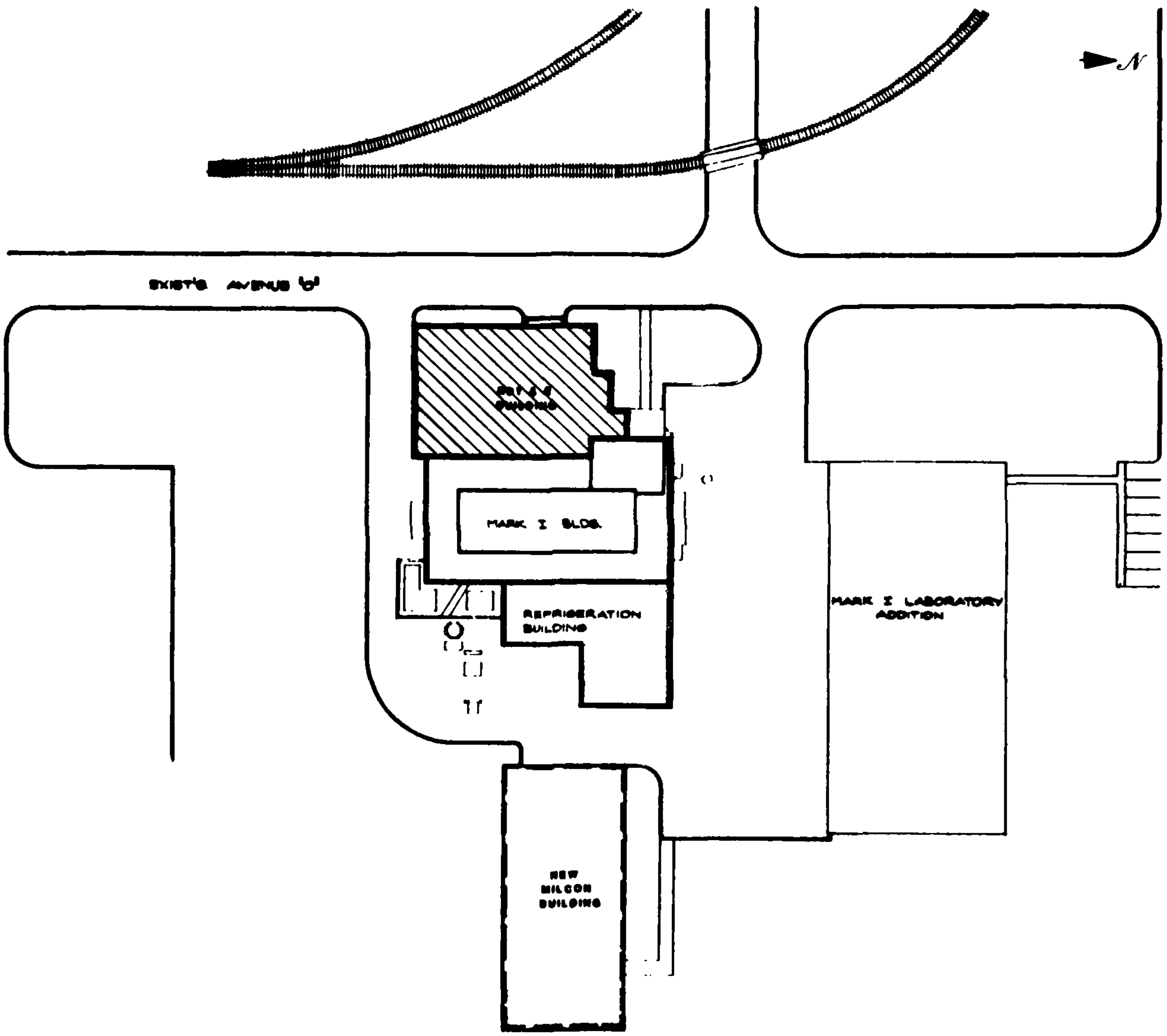


Figure 6. AEDC site plan

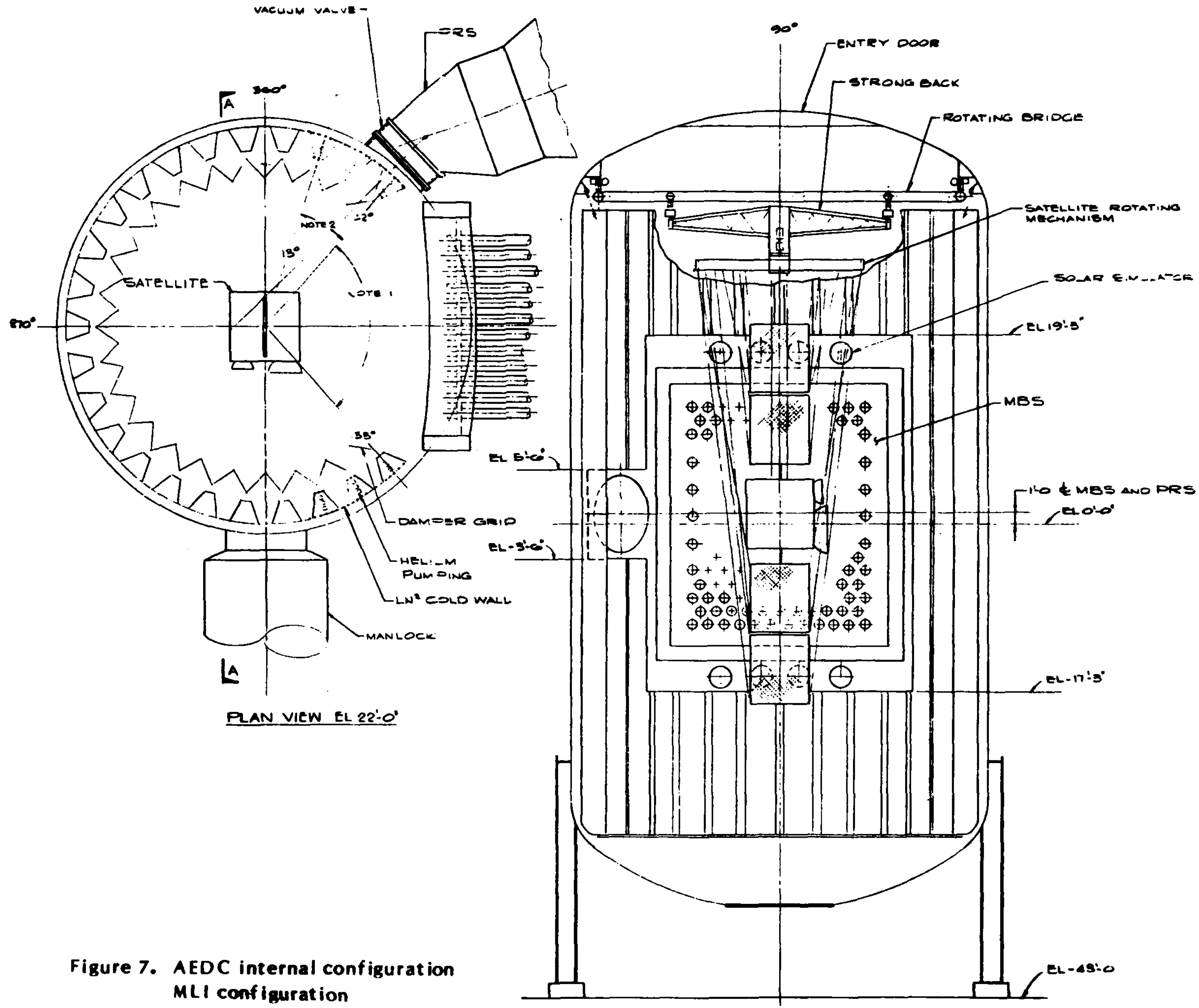


Figure 7. AEDC internal configuration MLI configuration

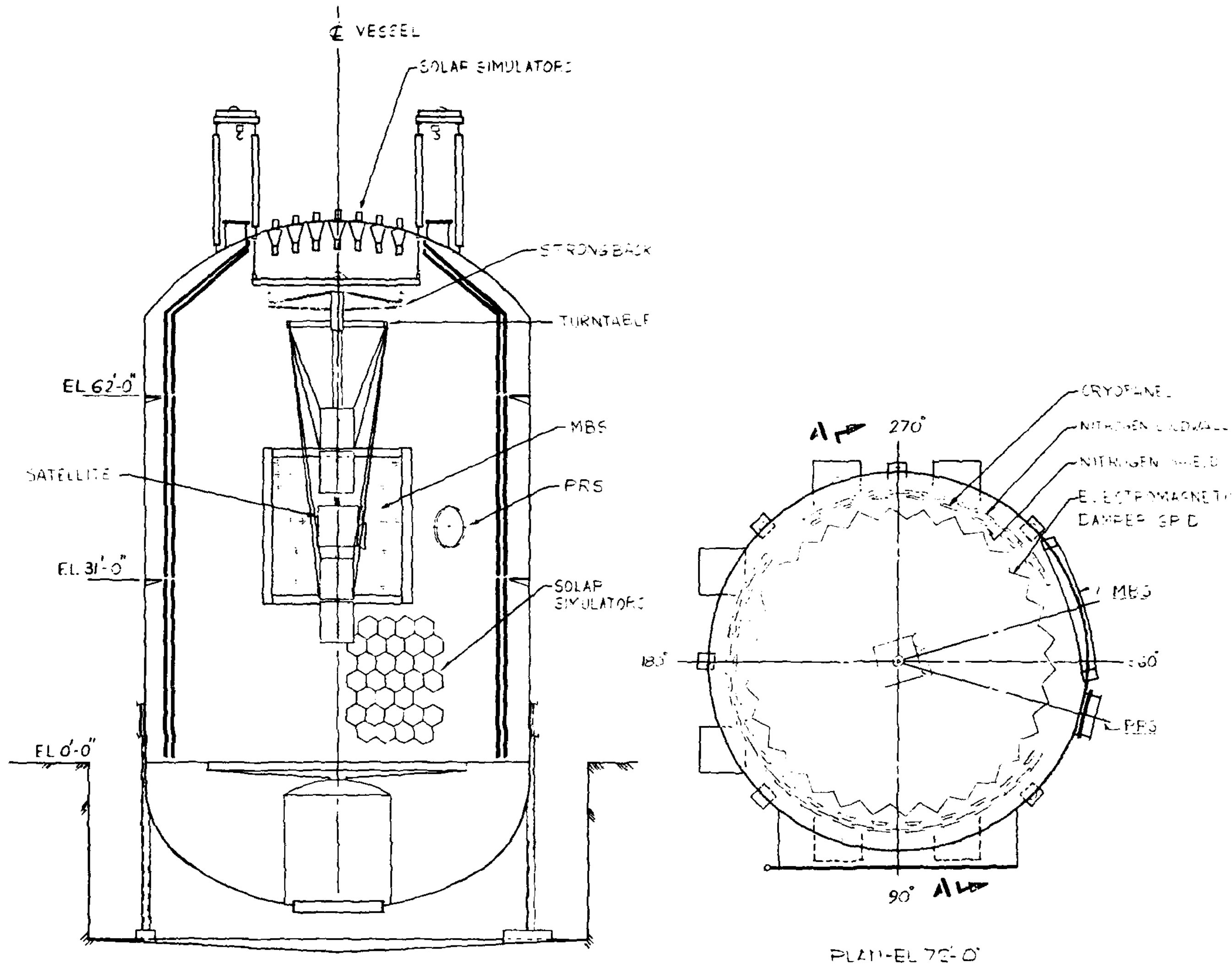


Figure 8. NASA internal configuration, PI configuration

withdrawal of the connecting cables before the shot, followed by reconnection after the test. The disconnect will be remotely activated from the AGE room as part of the satellite pre-shot checklist or from a control panel at a viewing port in the tank. The tank reference design will include a capability for a remote-controlled power disconnect system with a total capacity of 10 kW, dividable into three separate circuits (six lines), plus 30 low-current signal lines.

There has also been emphasis on the reduction of metallic surfaces which would be near the test object. These metallic surfaces are devices such as the photon source itself, the spacecraft entrance door, the test object suspension device, and the work floor. The test object suspension device, which might be very close to the spacecraft, has been designed of dielectric material to minimize the metallic surface exposed to the test object.

2.3 COMBINED PHOTON SOURCE

The combined photon source, consisting of the modular bremsstrahlung source (MBS) and the plasma radiating source (PRS), when fired simultaneously provides the range of spectra and the total fluence desired to achieve the DNA SXTF requirements.*

The principal areas of concern with regard to the combined sources have been:

- Geometrical layout of the source to achieve desired uniformity, divergence, and planarity in the simulation volume.
- Jitter and timing associated with firing both sources together.
- Mechanical interface to support integrated design for 200 MBS modules and the single-unit plasma radiator.

A major concern relating to the integration of the combined photon source for AEDC or NASA was the location of and angular displacement between the MBS and the PRS. Consideration was given to possibly splitting the MBS on either side of or above and below the PRS. An analysis and engineering evaluation of these options (Ref. 3) indicated that, although some improvement in a few of the technical parameters at the target plane could be achieved by such an arrangement, the overall effects were not desirable. The large spread in the arrival angle of the MBS fluence, along with structural constraints for both source manufacturers at both AEDC and NASA meant that the initial configuration concept, placing the MBS and the PRS side by side at the tank centerline, was the preferred configuration.

*Described in a separate, classified report to DNA.

Triggering of the two photon sources to achieve sufficient simultaneity of x-ray outputs appears to be feasible based on using an output from the PRS to trigger the MBS. However, an extension to the PRS water line may be necessary to increase the time between the output signal from the PRS switch and the x-ray output. Data on switch jitter has been obtained for a representative switch and appears to be acceptable. Figure 9 shows the maximum dimension of the PRS (~21 m) which MLI and PI anticipate for PRS water lines.

Existing structural constraints are also a serious consideration, particularly at the AEDC site. Vertical columns which support the massive structure of the existing building cannot be removed and the MBS must fit between these supports; thus, the diameter of the PRS and its angular arrangement with respect to the vessel tangent are highly limited (see drawings and discussion of MBS and PRS subsystems in following subsection).

2.3.1 Source and Source Integration

At present, two candidate source manufacturers, Physics International, Inc. (PI) and Maxwell Laboratories, Inc. (MLI), have different integration requirements. These are treated separately for each candidate vessel system in the following paragraphs.

NASA 'A' Chamber - PI Sources

The structure to integrate and support the MBS at the vessel end is a thick (4-6 inches) stainless steel source plate. The MBS concept consists of three groups of modules. Each group has four parallel columns, each column containing 16 modules for a total of 64. Use of a curved cylindrical source plate of about 100-ft radius (31 m) allows the module groups to fan out, enhancing the maintenance access space (see Figure 10). The modules in each 4-column group are further subdivided vertically into four groups of 16, each of which is connected at the opposite end from the vacuum vessel to its own Marx tank. The individual modules are linked to the source plate via a bellows assembly which permits articulation only. Axial movement due to vacuum vessel deflection or thermal gradients is relieved via sliding joints at the Marx tank. The seal between the module and source plate consists of two concentric O-rings; the space between them may be evacuated and connected to a leak detector. Loads due to structural weight and those developed during vacuum operation are transmitted to the vessel shell via a box girder stiffener system completely surrounding the source plate.

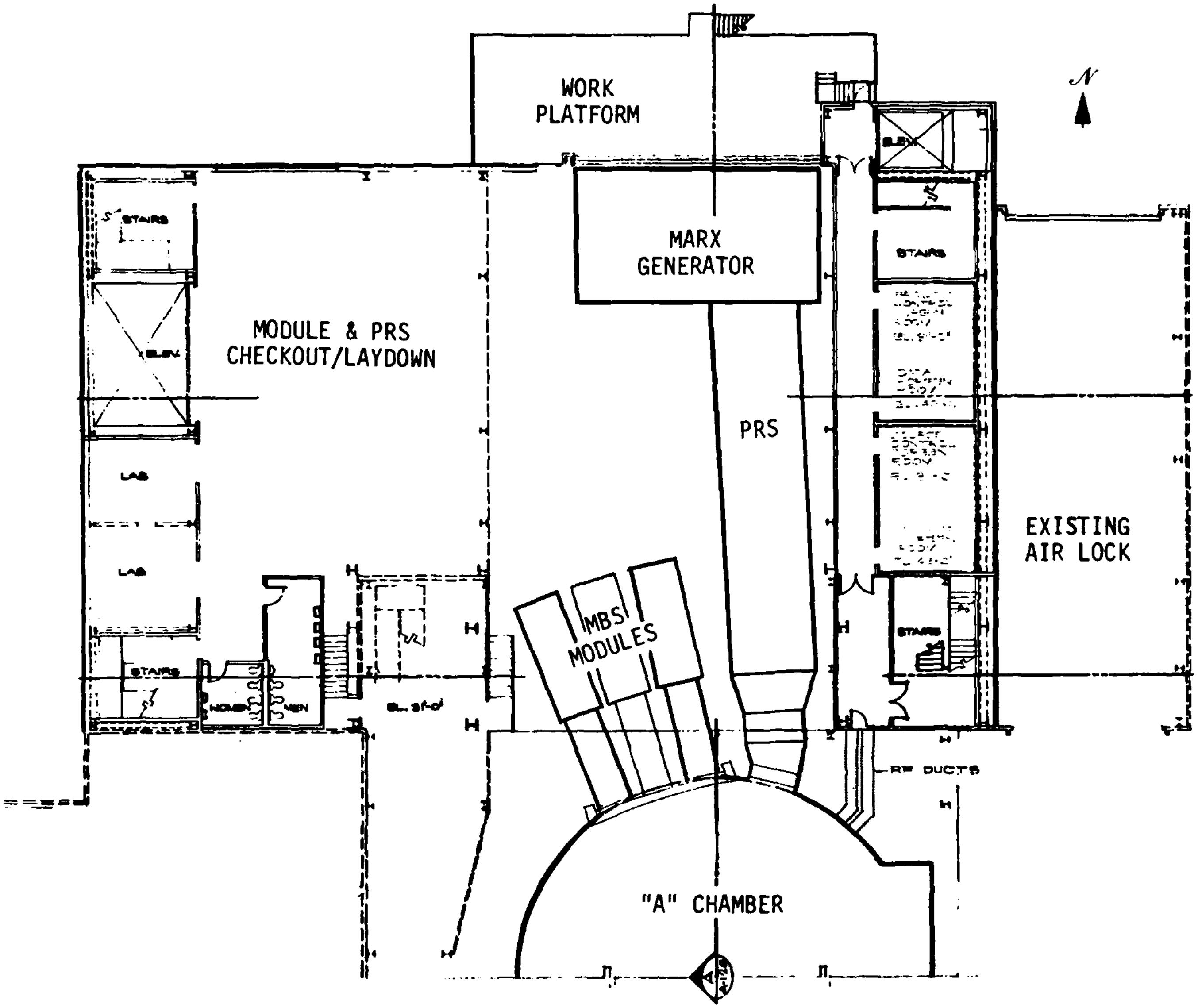


Figure 9. NASA MBS/PRS arrangement, PI configuration

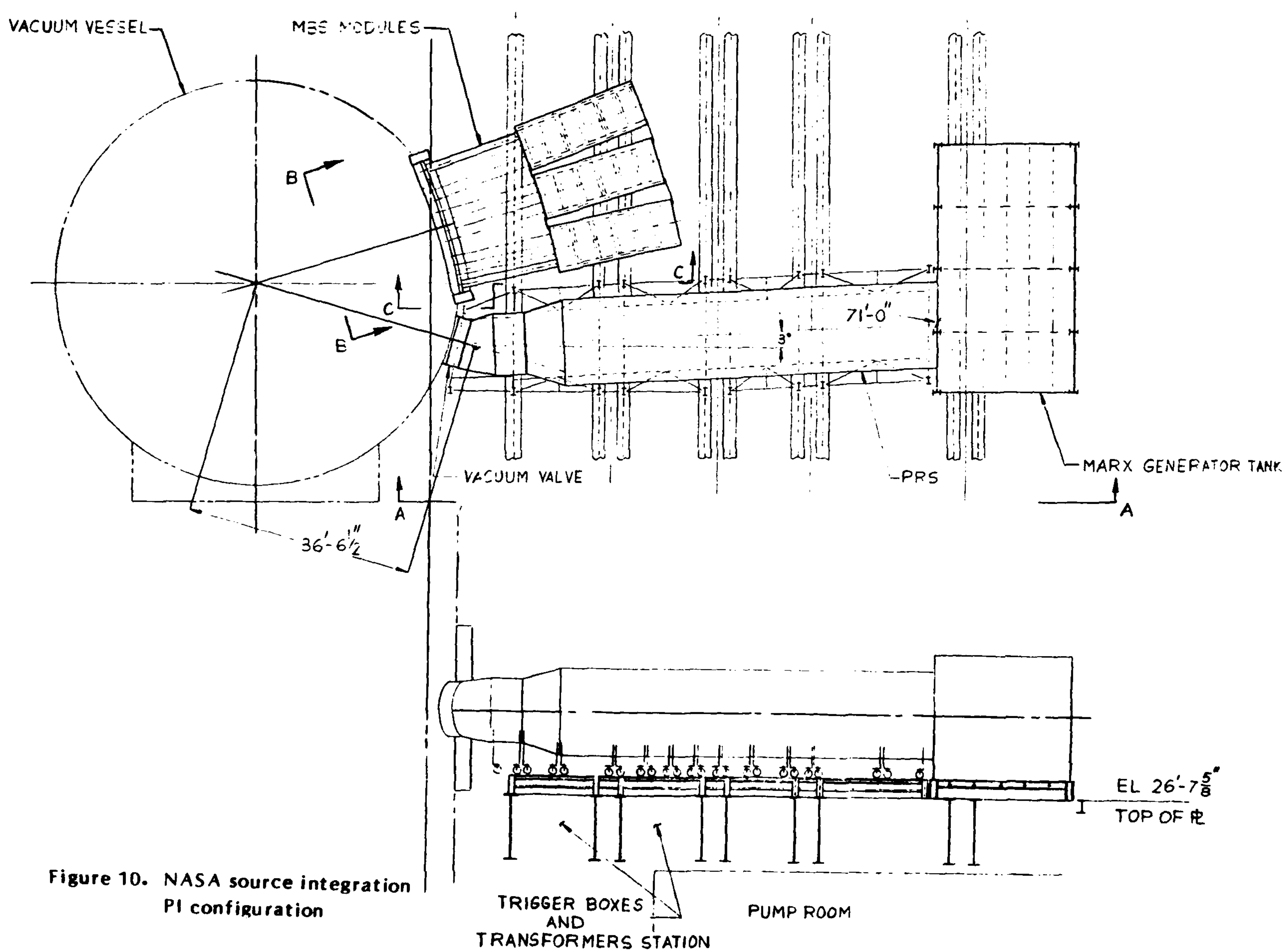


Figure 10. NASA source integration PI configuration

The PRS is connected to the vacuum vessel via an 83-inch-diameter (2.1 m) valve with a flange-to-flange thickness of 24 inches (60 cm). The purpose of this valve is to allow replacement of the source wire and cleaning of insulators after each shot while the vessel remains under vacuum. As the diameter of the valve increases, the thickness of the valve increases rapidly due to stiffening and mechanical requirements; thus, this integration may run into subtle difficulties if other than a standard valve design is used.

At the far end of the long transmission line, the PRS is connected to a large Marx generator tank. Both the PRS line and the Marx generator tank are arranged on a platform ~5 feet (1.5 m) above the work floor. This platform is covered on the sides and bottom to form a trough. Any oil or water leakage from the Marx generator tank or the PRS line will be collected in this space. The location selected for both the MBS and PRS integration causes the least interference with the piping around the vessel, and will not require removal of any longitudinal vessel stiffeners.

NASA "A" Chamber - MLI Source

The source plate structure devised to integrate and support the MBS at the vacuum vessel end is a thick (10-15 cm) plate similar in dimension to that used for the PI source. The MBS concept consists of a group of modules arranged in a hexagonal array. In this concept, a coupling is provided in each module near the source plate capable of permitting all the articulation necessary for projected deflection. The seal between the module and source plate consists of two concentric O-rings, with the space between evacuated and connected to a leak detection device. Loads due to structural weight and those developed during vacuum operation are transmitted to the vessel shell via a box girder stiffener system completely surrounding the source plate. The location selected for MBS and PRS integration causes the least interference with the piping around the vessel, and will not require removal of any longitudinal stiffener on the vessel.

AEDC Mark I - MLI Source

Integration to the vacuum vessel is via a source plate almost identical to that used for the NASA "A" chamber, adapting to the smaller vessel radius again via a box girder frame (see Figure 11). The MBS concept is a similar hexagonal array to that used for the NASA "A" chamber except with fewer modules. The location selected for integration of the MBS and PRS has the least affect on the existing building (see Figure 12). Sections of the present west wall must be removed for MBS and PRS penetrations. The width

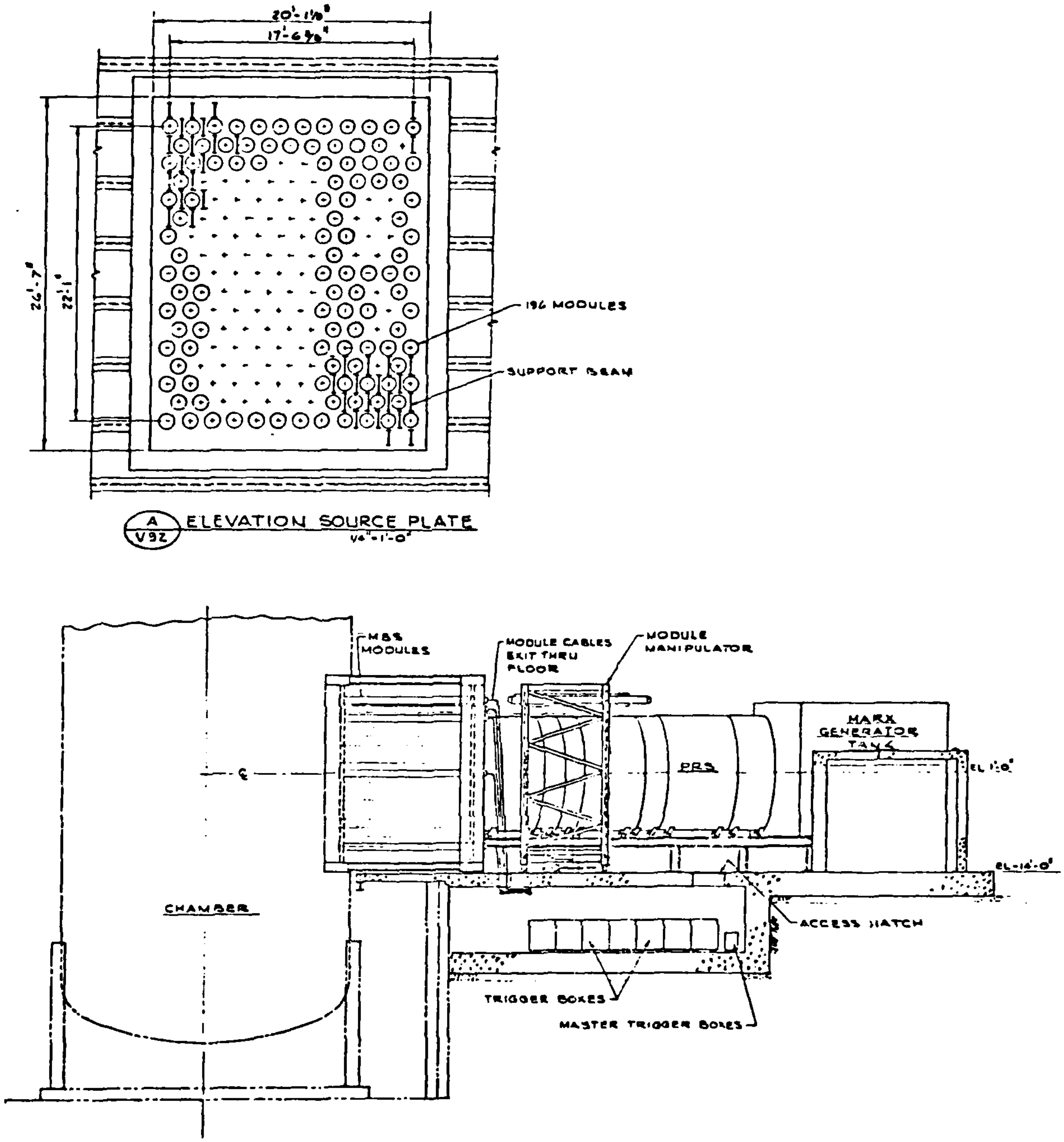


Figure 11. AEDC source integration, MLI configuration

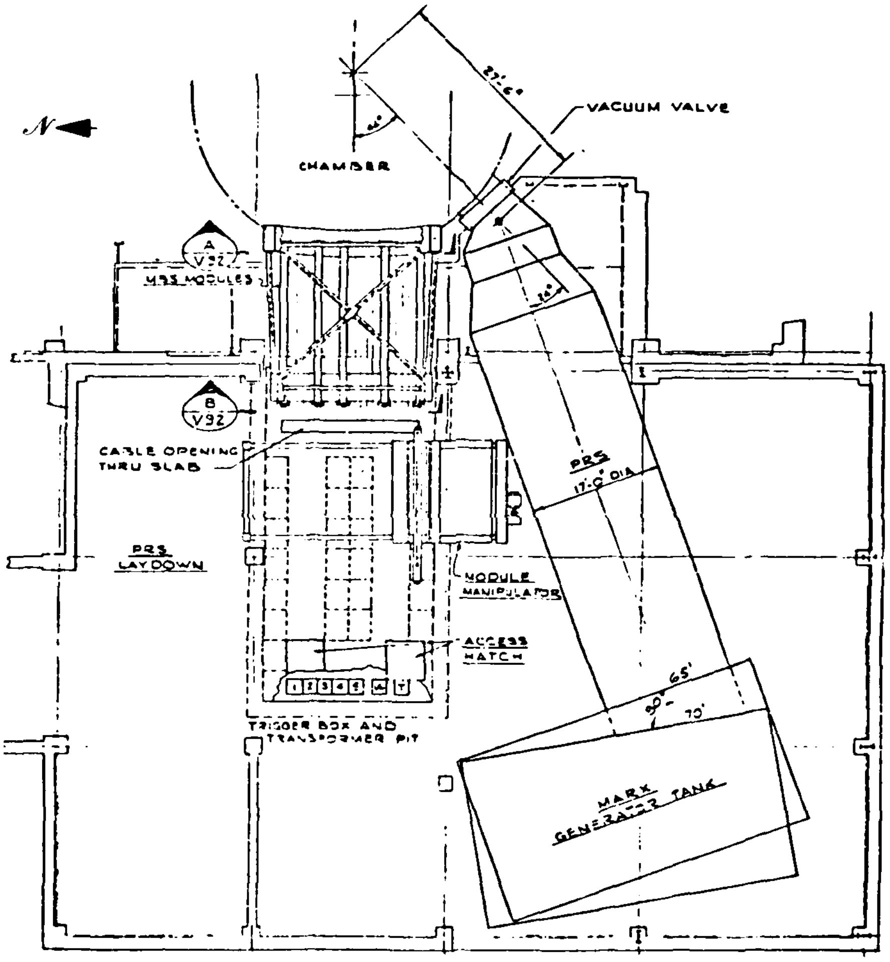


Figure 12. AEDC MBS/PRS arrangement, MLI configuration

of the MBS module array is fixed by the two existing roof support columns. The PRS and Marx generator tank have a 7-foot-high platform which will be used for leakage containment. Below the MBS, a pit is provided for transformers and trigger boxes. The width of this pit is limited to 22 feet because of existing buttresses supporting the wall of the building below grade.

AEDC Mark I - PI Source

The vacuum vessel integration technique is essentially the same as that used at the NASA 'A' chamber except that the box girder frame around the source plate must adapt to a smaller-radius vessel (6.4 m vs. 10 m) to the source plate. The MBS concept is the same as at NASA except that the axis of the three 4-column groups must be parallel to fit between key structural columns. Therefore, a flat source plate is preferred. The location selected for MBS and PRS integration causes the least interference with the existing building around the chamber.

There is a platform ~4 feet (1.2 m) high under the MBS Marx tanks. The PRS and its Marx generator tank are located on a platform 8 feet (2.8 m) high; the sides and bottom of this platform are covered to provide a storage area in case of leakage from the PRS or Marx generator tank.

2.3.2 Multipurpose Shield

A multipurpose shielding device is required between the photon sources and the test object to perform the following functions.

1. Debris emanating from the x-ray sources might enter the space chamber and contaminate the test environment or the test object; therefore, a debris shield is needed. For the PRS, this debris shield will have to withstand a rather severe plasma pulse and attendant shock fronts. The actual amount of material debris blown off the MBS diodes is not known at this time, but the diode faces tend to become abraded after several shots. Both the PRS and the MBS emit electrons which should be prevented from entering the test chamber.

2. Electromagnetic noise emanating from the sources can mask test object EM measurements. An EM noise suppressor for the PRS and for the MBS array is contemplated for inclusion in the multipurpose shield. This noise is separate from possible EM noise caused by return currents that get outside the PRS or MBS transmission lines and

radiate noise outside the vessel. The externally radiated noise will have to be treated as a machine design EMC/EMI design problem.

3. A thermal protection barrier must be established between the MBS and the test object. The test object thermal view of the space taken up by the large MBS surface (~7 x 7 m) must not appear as a 'warm' surface in comparison to the cold walls which cover most of the surface of the vessel. A low-emissivity material ($\lesssim 0.2$) should face the test object.

To reduce the potential differential thermal expansion problems on MBS diodes, the inside surface of the MBS source plate must not view the cold walls and must remain at about room temperature. Therefore, the surface of the multipurpose shield that faces the MBS should have a high emissivity ($\gtrsim 0.85$).

4. Collimation of the x-ray energy from the PRS and MBS may be desirable for two reasons. The amount and location of personnel radiation protective shielding outside the vacuum vessel will be partially dependent on the direction and intensity of the x rays and high-energy electrons from the sources. There is also a need to control the amount of backscattered electrons created by x rays striking the inner surface walls of the vacuum vessel. Collimation of the MBS would reduce the tank surface area exposed to the x rays.

Multipurpose Shield Reference Design

An MBS multipurpose shield is presently envisioned to consist of a rectangular steel collar around the source plate, extending about 2 to 4 m inside the vessel, which would serve as a collimator. Individual collimators on each diode were considered to be an unduly complex method which might have severe impact on MBS design and operation. Mylar and thin aluminum (or aluminized Mylar) sheets would cover the collar opening at the edge closest to the test object, providing debris, electron, and thermal barrier functions. A combined thickness on the order of 20 mils (0.5 mm) of Mylar and 3 mils (0.076 mm) of aluminum is suggested. Experiments are planned to determine the tradeoff between reducing the thickness of the Mylar to increase x-ray output compared to the possible decrease in electron stopping ability.

A wire mesh screen placed between this outer barrier and the MBS diodes may be needed as an EM noise shield. It may be possible to integrate EM noise, thermal reflectivity, and electron barrier functions into a single aluminized Mylar sandwich sheet.

The PRS multipurpose shield poses a particular problem in that the explosive nature of the plasma source will probably destroy at least portions of the debris barrier on each shot. Therefore, the debris barrier device will have to be accessible for replacement after each shot. Access to perform this task will probably be included in the PRS nozzle design, which integrates the gate valve located between the PRS and its penetration port in the vacuum vessel.

No reference concept design for the PRS multipurpose shield is presently available. A preliminary design effort in FY1981 is to address PRS nozzle physical configuration and tank integration design.

2.3.3 Source Service Systems

The water and oil storage tanks for the MBS and PRS are located outside the RDT&E building and buried underground. At AEDC, where the temperature would be very low in the winter, the storage tanks are covered with heating blankets to prevent the temperature of the oil and water from dropping below the minimum limit. At NASA, the support equipment for the oil and water service (such as the deionizer, degasifier, and regenerators) are located outside, but at AEDC these items are located inside existing buildings on the south side. The piping from this equipment enters the new RDT&E building and proceeds to a point adjacent to the specific source it serves. It terminates there at a shut-off valve. The source manufacturer has the responsibility for the design of the manifolds and other valves and controls associated with specific operation of the sources beyond the shut-off valves.

2.4 MBS PHOTON SOURCE

The MBS photon source provides the high-energy portion of the x-ray environment.

2.4.1 Background Issues

The MBS x-ray source design can be divided into those areas associated with x-ray output characteristics and those associated with the mechanical and electrical aspects. Pertinent x-ray source characteristics include:

- Fluence
- Spectra
- Time history

- Geometrical factors (e.g., uniformity, planarity, divergence)
- Repeatability
- Failure identification and reliability/maintenance factors

A discussion of each of these factors is beyond the scope of this report; suffice to say that the modular bremsstrahlung source (MBS), consisting of ~200 modules operating at 80 to 100 kV, but with the inherent capability to operate at up to 200 kV, contained in an ~50 m^2 area, is currently thought to produce acceptable x-ray characteristics. These conclusions were reached after studies comparing potential source characteristics and x-ray effects produced by them with those associated with a range of weapons, blackbodies, the enemy defense model, and potential weapons characteristics designed to maximize effects. Recent data on individual modules indicates that the output spectra and time history of a single module is acceptable. Data on multiple-module performance indicates that sub-arrays of seven or eight modules also provide satisfactory performance and that extrapolation of the characteristics of the individual modules to a full 200-module array will provide the desired x-ray environment.

The mechanical and electrical aspects of the MBS have only recently been addressed in some detail, with much of the previous emphasis on the development of modules with acceptable x-ray output characteristics. The mechanical and electrical aspects of the problem can be conveniently divided into the following areas.

- Mating of the MBS array to the tank.
- Design of the debris/EM/emission-suppression/thermal control system.
- Jitter of modules and triggering subsystems.
- Electrical characterization of modules.
- Construction of reliable modules.

Preliminary mechanical design of the tank-source interface was developed by NEC in concert with each source manufacturer. Problems have been identified with respect to the size and thickness of the source plate, packing density of the module, vacuum leakage associated with 200 modules, accessibility for maintenance, and thermal control for operation in a cold wall environment. These problems have all been addressed and apparently resolved.

Analysis of acceptable module jitter has been performed, and test data was collected. More work in this area is required as additional data becomes available, with tradeoffs between basic module jitter and timing subsystem jitter being a competitive design issue between the source manufacturers.

The degree to which the x-ray output of each module can be characterized by the electrical signals measured on each module has received considerable attention because of the convenience of using electrical diagnostics rather than x-ray output diagnostics. Electrical signals are convenient for timing and jitter analysis as well as for determining potential source malfunctions.

Problems associated with the construction of 200 MBS modules are now being addressed. A fundamental question remains as to the feasibility of translating the design of a laboratory source into one that can be manufactured with high operational reliability.

A remaining issue is the need for and specification of source collimation, and the EM noise levels and frequency content generated in the source (as yet unmeasured) and the details of the diode grounding to the source plate. These problems and a thermal barrier and debris shield function all fit under the "multipurpose shield" previously identified. This multifunction device remains a critical technical and design issue.

2.4.1 MBS Reference Design

Due to the competitive nature of the MBS development, two separate designs for both the modules and the MBS support structure and tank source plate have been developed. Basic layout diagrams were shown in the NEC drawings (Figures 9-12). Generalized design parameters are as described below.

MBS modular array: ~200 modules.

MBS array area: ~50 m^2.

Array configuration: 1:1 width-to-height ratio.

No more than one-half of module weight to be supported by tank.

This reference design will use the following MBS reliability definitions. (These definitions and specifications may be revised in the MBS RFP.)

Array reliability: No more than 10% of modules may be allowed to fail or require major maintenance during a 100-shot sequence; DNA has indicated that an MTBF value of 500 shots per module is a goal.

Major maintenance:

Array cannot be made operational in less than 2 hours.

Access to modules inside tank is required (break vacuum).

Minor maintenance:

Periodic servicing that does not interrupt test operations.

Corrective maintenance which does not break tank vacuum and which is completed in less than 2 hours.

A number of mechanical stress and movement criteria have been agreed to between NEC and the source manufacturers, which were pertinent to the source integration, structural design, and analysis efforts, but they are not included in this report.

Removal of MBS modules from the array will be done by means of manipulator systems provided by the source manufacturer. A removed module will be carried by the facility overhead crane to a maintenance location. MBS diodes that are bolted to the MBS source plate can be maintained in place and reached from inside the vacuum vessel via a permanent maintenance platform connected to the top girder of the source plate frame on the inside of the vacuum vessel. It is a two-person-movable platform capable of supporting about 2000 lb (909 kg). It is desirable to have a capability to provide work platforms for two to four 2-man teams to do MBS maintenance simultaneously. A structure to hold the debris shield would stand about 2-4 m inside the tank in front of the total MBS array.

The source plate and MBS foundations are part of the tank and structures design, whereas rear module support, maintenance dollies, and all oil, gas, and other interfaces and connections to the modules are the source manufacturer's specific design and procurement responsibility. The facility contractor will install all fluids storage facilities and will provide the fluids to the source manufacturer near the MBS.

2.5 PRS PHOTON SOURCE

The PRS photon source provides the low-energy portion of the x-ray environment.

2.5.1 Background Issues

The PRS x-ray source design can be divided into those areas associated with x-ray characteristics and those associated with the mechanical and electrical aspects. Pertinent x-ray source characteristics include:

- Fluence
- Spectrum
- Time history
- Geometrical factors (e.g., uniformity, planarity, divergence)
- Repeatability

A discussion of each of these factors is beyond the scope of this document; suffice to state that the PRS source, consisting of a combination of Ti, Ca, and/or Aℓ wires or a puff-gas source in conjunction with a pulse generator such as Blackjack V, is currently thought to produce acceptable x-ray characteristics. These conclusions were reached after studies comparing potential source characteristics and x-ray effects produced by them with those associated with a range of weapons, blackbodies, the enemy defense models, and potential weapons characteristics designed to maximize effects. Recent experiments indicate that desired outputs and spectra can be achieved with the Blackjack V design, and the baseline source for the PRS portion of the SXTF is the Blackjack V.

The mechanical and electrical aspects of the PRS have only recently been addressed in some detail, with much of the previous emphasis on obtaining suitable x-ray output characteristics. The mechanical and electrical aspects of the PRS can be divided into three areas:

- Mating of the PRS anode/cathode structure to the tank.
- Design of the debris/EM/emission-supression/thermal-control screen.
- Ability to synchronize the PRS with the MBS.

Mechanical designs of the interface were developed by NEC in consonance with each source manufacturer. Problems have been identified with respect to the size of the gate valve required to obtain an acceptable x-ray coverage angle in the tank, given that the PRS source must be accessible between shots without repressurizing the tank, and given the mechanical constraints on the closest point at which the plasma source can be placed with respect to the tank. Other mechanical problems include identifying and designing for stresses (such as thermal loads and impulsive loads during firing).

Several design concepts for a debris shield, EM screen, emission control, and thermal control surface have been expressed including Kapton foils, optically transparent metal screen, and thin aluminum foils. Sufficient data on debris and EM noise emanating from the PRS has not been obtained to permit a final choice as to design approach.

A preliminary analysis of the timing and jitter with respect to the PRS has been performed, resulting in a concept to obtain the basic timing reference from the next-to-last output switch from the PRS. Evaluation of the desired threat environment indicates that PRS and MBS synchronization within ±5 nsec is satisfactory. Initial discussions with the source manufacturers indicated that this jitter limit could be acheved, but no demonstration or verification of synchronization has been performed to date. The maximum allowable synchronization limits have not yet been established, and further analysis will have to be performed if larger jitter ranges occur. Sufficient lead time to synchronize the MBS x-ray output with the PRS appears to be attainable from a PRS water line with a length of about 70 feet (21 m).

The major issues with regard to the PRS which still have not been fully resolved include:

- Demonstration of a wide (~90°) radiation coverage angle, and implication on the gate valve design, closest point of approach of the PRS to the tank, and the angle of the PRS water line relative to the tank normal (this angle is highly constrained at both AEDC and NASA).
- Radiation output characteristics at various angles from machine.
- Design of an integrated debris shield, EM noise screen, electron backscatter control, and thermal control surface (for compatibility with cold wall operation).
- Identification of sources of operational stress (thermal, impulse loading during firing) and developing suitable designs to accommodate the loads.
- Design and demonstration experiments for acceptable timing and jitter.

The radiation coverage angle is determined by the location of the PRS source relative to the tank wall and the size of the largest practical gate valve. Minimum approach distances for the water line to the tank are on the order of 0.5 to 1 m. To obtain full coverage for a 12-m baseline satellite located 7 m from the source, a half-angle greater than 40° is required. Corresponding dimensions required for the gate valve diameter are in the range of 1-2 m. Gate valves up to 2-3 m are procurable without special design and development, but in the event a special valve is designed, its thickness may increase rapidly beyond acceptable levels.

Iterations of the water line length, width, location, coverage angle, and gate valve design for both AEDC and NASA indicate that there is very little margin for change in the present conceptual arrangement.

Design of a practical integrated PRS shield to stop debris, suppress RF noise generated in the source, minimize electron emission, and thermally isolate the PRS source from the cold wall environment appears to be quite feasible. However, the design cannot be finalized in the absence of data on debris size and mechanical shock, EM noise levels and frequency content, and definition of spectral range from PRS source operation. In this regard, a shield which is too thick will unduly attenuate x rays, while a shield that is too thin will not withstand mechanical shock or stop debris particles. A concept has been proposed consisting of multilayers of Kapton (high strength and low Z), an x-ray-transparent screen, and a thin layer of aluminum for thermal control and EM noise suppression. Experiments to resolve these issues are to be performed in FY81.

2.5.2 PRS Reference Design

The reference design for the PRS is based on the Blackjack V. The transmission line is a 16-foot-diameter (4.9 m), 50-foot-long (15.5 m) steel cylinder attached to a Marx tank at the far end and connected directly to the tank through a gate valve of ~2 m diameter at the plasma end. Maximum estimated dimensions for the transmission line diameter and length (5.2 and 23 m, respectively) are included in the site integration design (Ref. 2). A preliminary plasma diode and 'nozzle' configuration design to integrate into the vessel gate valve is to be performed by each source manufacturer in the beginning of FY82.

A gate valve is to provide isolation between the tank and the PRS radiation source region for replacing wires or cleaning diode surfaces, probably after each shot.

Oil storage for the Marx tank is provided by underground tanks outside and clear of the facility building.

De-ionized water is provided for the transmission line.

Assembly and work space is provided on one side of the PRS transmission line.

The reference design will provide for procurement of the PRS gate valve, the PRS foundations, oil and water storage, and prime AC power as an integral part of the tank and structure contract. All other elements of the PRS are considered part of the source procurement.

2.6 VACUUM SYSTEM

From the experimenters' view, overnight pumpdown (6 to 12 hours) is desirable. Pumpdown time is a function of the size and cost of the roughing or mechanical pumping system. For both AEDC and NASA, pumping capacity is satisfactory to achieve these pumpdown times. The primary factor in determining actual pumpdown time will probably be leakage.

Repressurization of the tank is the process of bringing the tank back to atmospheric pressure. Two techniques are used: fill the tank with nitrogen and then purge the tank with air, or bring the tank back to pressure using dried air. Vaporizing liquid nitrogen for repressurization is both costly and dangerous, whereas repressurization with air requires that the air be dried and heated to control humidity.

The vacuum system for both candidate facilities consists of a conventional vacuum pumping system with roughing pumps, fore pumps, booster pumps, diffusion pumps, and a cryo pumping system cooled by a liquid nitrogen and gaseous helium system that is capable of evacuating the chamber to 10^{-5} torr or below. Repressurization of the vessel is accomplished by introducing pre-dried air into the vessel. This technique is used to prevent moisture condensation from accumulating inside the vessel during repressurization.

2.7 COLD WALLS AND CRYOGENIC SUBSYSTEMS

Cold walls enable the spacecraft to radiate the heat generated in a power-on configuration when simulated space conditions of high vacuum are imposed.

Initial requirements for the SXTF led to a complex, segmented cold wall configuration controlled, by segment, over a -200 to 0°F (-93 to -17°C) range. Further discussions with TRW and GE indicated that a constant-temperature cold wall uniformly adjusted over the range stated was sufficient.

During discussions with AEDC and NASA, it was noted that the cold walls at these facilities were almost full-coverage LN_2 at a temperature below -300°F (-150°C). The spacecraft manufacturers indicated that such configuration and temperature would be acceptable to them.

The cold walls also act as a temperature baffle for the helium cryogenic pump subsystem and are, in effect, part of the overall vacuum system.

Both AEDC and NASA have existing diffusion pumps which provide part of the high-vacuum pumping capability. There has been a general SXTF requirement to limit the use of oil diffusion pumps due to the possible hazard of oil contamination of sensitive spacecraft. Both candidate facilities appear to have sufficient cryo pumping capability to achieve the 10^{-5} torr vacuum without the use of diffusion pumps.

In both facilities, modification to cold walls/cryo panels will be required, the extent of which will be subject to final definition of satellite operating limits. The area in front of the MBS source plate and PRS penetration must be cleared of cold walls and helium cryo panels, along with associated piping modification.

The pumping system for the nitrogen portion of the cryo panels is for liquid nitrogen only. Satellite operating limits may impose a need for gaseous nitrogen circulated through some of the cold wall panels which would require additional equipment and piping modifications.

2.8 ELECTRON BACKSCATTER CONTROL

The function of electron backscatter control is to reduce unwanted electron emission from the tank wall, cold wall, and damper to make the tank appear more like free space.

2.8.1 Background Issues

Several approaches to emission suppression were considered, including:

- Passive low-Z coatings
- Active charging grids
- Grounded screens to suppress radiated EM fields in the vicinity of space-charge-limited emission

The passive low-Z coatings are the most attractive because they do not require high voltages or an integrated damper/suppression system, which becomes quite complex. Calculations were performed, and are still underway, which indicate that a passive low-Z control system may be suitable, providing a significant fraction of the test object is composed of quartz, fiberglass, aluminum, or materials of higher atomic number. Because of the construction technique of existing and proposed spacecraft, it appears that this condition will be satisfied, but there is still some concern that an active system may be necessary if a relatively small vessel such as AEDC is used.

Investigations are now proceeding regarding the selection of materials which are suitable from an emission control point of view as well as from an environmental compatibility point of view. Two candidate materials now being considered have been used to coat thermo-vacuum tanks in the past -- Black Velvet, made by MMM, and Catalac Black, made by Bostic, Fince & Co. Investigations during the next year will determine the composition and suitability of these materials as a tank backscatter control material.

The primary issues remain determination of the real need for an active suppression device and, if needed, development and design of such a mechanism. If a passive coating is sufficient, further work to determine the cold wall, vacuum, and radiation compatibility of the selected material is needed, along with material life testing and tests to determine coating thickness.

2.8.2 Electron Backscatter Control Reference Design

A coating material such as Black Velvet or Catalac Black ($Z < 6$) is proposed to coat all cold wall surfaces viewed by the test object. A thickness of ~3 mils (0.076 mm) is anticipated to effectively reduce electron emission.

2.9 EM DAMPER

The damper is an absorber of EM energy to make the metallic tank cavity appear to be more like free space.

2.9.1 Background Issues

Without a damper, prolonged oscillation in the enclosed metallic tank would be set up which might mask the desired free-space response and could overstress the test object. A number of studies have been performed to support the design of the damper system, including:

- Analytical calculation on single- and multiple-sheet dampers at various locations within the vessel.
- 2-D and 3-D code calculations in cylindrical chambers of various sizes.
- Effects of large openings in the damper for practical reasons (e.g., doors, x-ray source areas, etc.).

The problem of developing a quantitative criterion arose because of the dependence on test object size and shape, tank size and shape, and the importance of specific response features. During the past year, both JAYCOR and MRC analysts have developed methods of evaluating simulation quality. Results of these analytical efforts will be a principal factor in selecting the final SXTF site.

Calculations for single- and double-sheet damper configurations placed at various distances from the test object in relation to the tank radius have indicated that a single cylindrical damper could fail to remove certain "modes," whereas a rippled damper could reduce the possibility of modes in the tank.

It was also found that damper requirements are less severe for nonsymmetric tanks particularly in which the test object is placed off the centerline out of the focal point of the tank.

One major issue still under investigation relates to the actual material to be used for a damper. Critical parameters are the ability of the damper material to survive an environment of high and low temperatures, x-ray radiation, electron bombardment, and high vacuum. The June 1980 UGT should give additional insight into this problem.

A second design issue concerns the actual mechanical design of the damper mesh sheet, the structure to hold the damper material, the manufacturability of the specified material, and the degree to which the damper sections must be fastened together. A 1-inch cotton net is presently available, and was satisfactorily used in the June 1980 UGT. Specification of the damper grounding to the tank is also required.

2.9.2 EM Damper Reference Design

The reference damper is a rippled damper with amplitude ±1 m, centered at 0.8R of the conductive cold wall of the tank. The damper mesh is 200 ohms/square ±20 ohms, made from cotton or man-made fiber thread. A mesh with a 90% see-through factor of 1- to 4-inch (2.54-10 cm) squares appears satisfactory. The damper should have a 1-year life, as a minimum. The impedance per square is established by coating the thread with a carbon-based polymer. A conceptual mechanical design and basic environmental criteria were provided to NEC. This design uses a circular shower curtain concept, with the damper hung as a coaxial drape drawn the length of the vertical cylinder. The photon source, selected areas of the working floor, the spacecraft suspension system, and openings for instrumentation, cable, and viewing ports are not covered. It is recommended that specific effort be made to ensure good electrical connection between damper panels. It has also been recommended that the damper and all other nonconducting or dielectric materials be provided a means of being electrically discharged. A concept of grounding the damper at many points in the tank indicates improved electron suppression. Experiments to evaluate this effect will be conducted in the fall of 1980.

2.10 ELECTRON BEAM SOURCES

The function of the electron source is to provide a source for electron-caused electromagnetic pulse (ECEMP) and combined SGEMP/ECEMP simulations.

2.10.1 Background Issues

ECEMP effects and combined SGEMP/ECEMP effects have recently been demonstrated to be important, and it is apparent that this capability is needed in the SXTF both for x-ray effects and for effects from the artificial trapped electrons produced by a nuclear burst.

The characteristics of electron and ion beams required for proper simulation have been discussed at a number of SXTF meetings, and are still the subject of research by the spacecraft charging community. The objective of a plasma environment for the SXTF should relate to system-level effects that are modified or caused by the space environment. Effects to be examined include SGEMP precharge effects on satellites, x-ray-stimulated discharge phenomena, and spontaneous discharges by nuclear-enhanced and natural space plasma. These objectives can be met through simulation of the effects of space electrons and ultraviolet light. Ions are not judged important for simulating these effects.

The capability for simulating various ranges of electron energies appears to be desirable. General considerations are:

- Low energies for charging of external surface.
- Intermediate energies for charge deposition into the bulk of outer dielectrics.

The need for charging of dielectrics within boxes for an SXTF test has not yet been established, and would require high energies for charging dielectrics in spacecraft cavities and for stimulation of currents within internal electronics. These are not considered system effects.

The most important issue at this time is agreement on the electron spectrum and fluence and a reference design for source placement and rastering to achieve desired coverage.

Placement of the low-energy sources presents a problem with respect to transport of the beam across the tank to the satellite in the earth's magnetic field. Either the low-energy electrons will have to be of relatively high energy, the guns placed near the satellite, or some type of geomagnetic field reduction will be required to facilitate the beam transport to achieve the desired coverage.

A very preliminary set of criteria (Ref. 4) for the electron guns has been defined. The general characteristics are:

Energy Range	Flux
1-25 keV	0.05 to 10 nA/cm^2
150-300 keV	0.1 pA/cm^2 to 0.1 nA/cm^2

2.10.2 Reference Design for E-Beams

Low-energy guns: 10 guns located uniformly around the lower portion of the tank to allow relatively uniform illumination of the test object.

Medium-energy guns: 2 guns located on the tank at the horizontal mid-line and near the photon sources. Guns are probably monoenergetic, with energies selectable over the 150- to 300-keV range.

2.11 GEOMAGNETIC FIELD REDUCTION

The potential function for the geomagnetic field reduction is two-fold:

- Reduce the SGEMP/ECEMP response perturbations produced by electrons turning in the earth's magnetic field (~0.5 gauss), which can be 10^3 times as high on earth in the SXTF as in orbit.
- Permit low-energy electrons used for ECEMP testing to reach the satellite.

The absolute need for geomagnetic field reduction for either function has not yet been established.

2.11.1 Background

Preliminary estimates of the effect of the geomagnetic field on the satellite SGEMP response were made early in the program. Reduction of the earth's magnetic field is considered immaterial to SGEMP response quality in the SXTF (Ref. 5).

The need for field reduction with regard to ECEMP simulation depends on the location of the electron guns and the desired energy range. Based on an assumption that electron energies of less than 3 kV are not needed, magnetic field reduction to 0.1 gauss or less will probably be sufficient for spacecraft charging (Ref. 4). Field reduction to 0.02 gauss is estimated to be the greatest reduction that would be necessary.

2.11.2 Magnetic Field Reference Design

The NASA chamber has a magnetic field reduction coil system installed. It is a three-coil system inside the vessel, and has been used in ion plasma experiments conducted at that facility.

A magnetic field reduction concept for AEDC would probably be much like the one at NASA. The effect of various Helmholtz coil configurations have been calculated indicating that a three-coil arrangement, with the middle coil at the vessel horizontal centerline and ~6- to 8-m spacing between coils, would reduce the field to very small levels.

2.12 SOLAR ILLUMINATION

There are several potential functions for a source of solar illumination, including:

- Provide a source for illuminating the solar arrays which, in turn, provide power to the spacecraft during the test.
- Provide a solar illumination capability for satellite tests other than those directly related to the SXTF.
- Provide a source of UV for use in spacecraft charging simulation.

2.12.1 Background Issues

The need for solar illumination has been raised at a number of SXTF meetings. An evaluation by TRW has indicated that there is no requirement, from the viewpoint of spacecraft manufacturers, for activation of the solar panels for testing purposes. Evaluation of the response of solar cells under x-ray radiation indicates that they do not need to be activated prior to x-ray exposure since the x-ray levels dominate the response. Therefore, no solar illumination system is being included as an SXTF requirement.

A high-quality solar source (good uniformity, match solar spectra, etc.) is a technically complex, physically large, and relatively expensive subsystem. There are solar illumination facilities in the United States (JPL and NASA/Houston) which are specifically designed for evaluating the solar response of spacecraft.

If it is necessary to activate the solar cells to establish the proper electrical connectivity, it has been suggested that some form of less costly and complex illumination, or a flash solar exposure, could be used. This approach has been used by spacecraft manufacturers for solar cell output measurements.

Current planning is to provide a separate UV source for spacecraft charging simulation.

The issue with regard to solar illumination concerns the electrical configuration differences of a spacecraft in the solar vs. non-solar condition. Blocking diodes or mechanical switches which function when solar-induced currents are charging the spacecraft batteries may present a different response from that which would occur when they are not functioning. Some electrical "spoofing" may have to be included in the test configuration to ensure having the proper electrical configuration under test conditions.

2.12.2 Solar Reference Design

At the NASA facility, there is an existing solar simulator array on the wall that will contain the photon sources. A portion of this solar array will be removed, but about half of the array ports will remain (those below the MBS down to floor level). Presently, these ports are equipped for obsolete carbon arc lamps; NASA intends to replace them with xenon solar lamps. There is also an existing solar array at the top of the NASA chamber.

At the AEDC facility, solar simulation is provided by an array of lamps suspended on temporary vertical towers inside the tank. These lamps do not provide a realistic solar spectrum but could probably meet SXTF solar requirements. It is intended to provide eight penetrations adjacent to the source plate on the AEDC vessel to provide a future modular solar capability, if needed.

2.13 ULTRAVIOLET ILLUMINATION

The function of a UV source is to provide a source of UV to simulate the role of the sun in ECEMP and/or SGEMP tests with regard to differential charging.

2.13.1 Background

The presence of UV can significantly alter the field distribution of a satellite in a charging environment. Therefore, a UV source may be required for establishing appropriate field distribution for ECEMP/SGEMP simulation. However, UV effects might be simulated by controlling the absolute potential of the spacecraft with respect to the tank. This situation brings about an "effects vs. environment" tradeoff.

Given that UV is required, the general features of a desirable UV source are not difficult to establish. The criteria defined in Reference 4 require UV illumination to produce emission of ~5 nA/cm^2 from a test plane of tungsten:

- Spectrum: Within the range of the solar spectrum that produces photoemission (~1000 to 3000 Å).
- Collimation is not critical but should provide a capability for shadowing objects.
- Area of coverage: The projected area of a 6 x 12-m test plane is the reference target.
- Location/coverage: The UV source should be movable so that illumination could come from any direction.

2.13.2 Reference UV Design

No specific reference design for a UV source has been developed, but hardware evaluation and a conceptual design are underway by SPIRE. It is also possible that the existing solar system at AEDC and NASA may produce, or may be modified to produce, sufficient UV to satisfy any SXTF requirements.

3. SXTF INSTRUMENTATION AND CONTROL

Instrumentation and control of the SXTF include not only the acquisition, recording, and processing of the experiment data but also the overall control of the test operation. The integrated control of the x-ray sources, the test object, and the data-taking equipment, along with control of the existing vacuum chamber equipment (pumps, cold walls, cryo panels) and newly added SXTF tank internals (e-beams, etc.) require that the instrumentation and control be viewed as a systems design problem specifically addressed as part of the AEDC or NASA modification.

3.1 INSTRUMENTATION AND CONTROL CONCEPT

The design of the instrumentation and control system for the SXTF RDT&E facility is essentially that defined in Reference 1, with the exception that the existing vacuum pumping and cold wall/cryogenic control functions will have to be incorporated into SXTF test operations. The basic facility modification plan calls for a very limited interface with these existing functions. Only status and emergency shutoff or inhibit actions will be provided to the SXTF controller.

The basic control approach for the SXTF will include a hierarchy of control levels which provide manual control capability at the local level; remote subsystem control; a central control capability for test operations; and a limited automatic control capability that can be selected independently to control emergency shutdown and accident prevention functions. The supporting computer subsystems should have sufficient capacity and flexibility to add selected control and accident prevention functions as experience with operating the facility develops.

The primary concept for operating the facility would be to depend upon man/machine interfaces to ensure the satisfactory status of all major subsystems prior to x-ray testing. Many of the individual subsystems have automatic self-control subsystems incorporated in their basic design, and these would be depended on to minimize the specific function selection involvement of the man/machine interface. Indeed, the facility computer system should have adequate capacity to take over performance of the more sequentially self-limiting control operations to minimize the man/machine interface functional involvement; however, a philosophy of total automatic computer control is not intended. Authorization to initiate test exposure will be man-instructed, based on subsystem-ready signals generated through subsystem automatic control systems, man-involved subsystem control systems providing system-ready information, or, in selected cases, fully automatic computer-involved subsystem control systems. In any event, a man-reasoning interface intervenes between the onset of testing and the interpretation of ready status.

A key criterion for the design of subsystem controls will be the inclusion of the ability to perform operational checkout and acceptance testing and local maintenance functions. This facilitates maintenance and checkout operations; however, these local control panels must have man-controlled inhibiting capability for operational safety reasons. Subsystem operational control panels and data readout panels will also be located in the various specialty screen rooms. These stations would provide the primary remote operating positions for individual subsystem controllers during normal test operations and would display important and needed measurements for normal operation of the subsystem. Where possible, these remotely operated control systems and display panels would be an integral part of the vendor-supplied subsystem incorporated into the facility-supplied control panels.

3.2 SXTF INSTRUMENTATION AND CONTROL AREAS

The functional categories of instrumentation associated with SXTF subsystems are:

1. Photon source instrumentation and control.
2. Existing vacuum vessel instrumentation and control.
3. SXTF tank internals instrumentation and control.
4. Test data and radiation environment.
5. SXTF data/computer subsystems.
6. SXTF test operation control.

A pictorial layout and interconnect diagram of SXTF instrumentation and control is shown in Figure 13.

All subsystems have interfaces with both the facility operations control console and the facility data subsystems. This feature provides the test operations controller with the option of having a few critical data signals and control functions directly displayed at the facility operations control console, and also provides a capability to have a fairly large set of data displayed on the computer terminal display unit, which is part of the operations control console. The content of this display can be selected and modified through software control in a preprogrammed form or directly from the console keyboard.

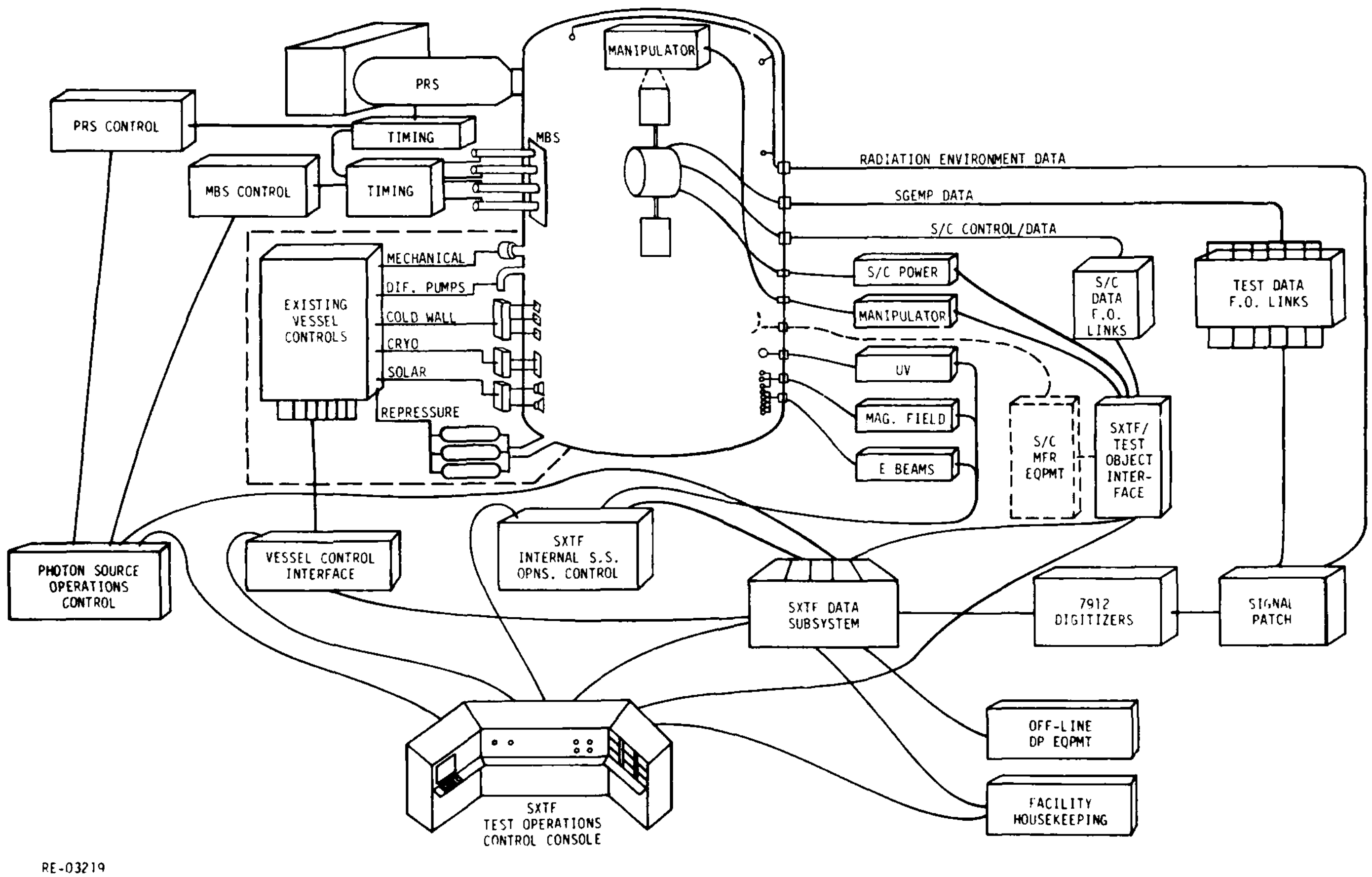


Figure 13. SXTF instrumentation and control diagram

3.3 SUBSYSTEM INSTRUMENTATION AND CONTROL DESCRIPTION

The following description of the instrumentation and control subsystems is intended to illustrate the general instrumentation concept and to identify the interfaces between the subsystems and the facility data and control equipment, and to provide guidance in specifying which equipment is to be provided by the subsystem vendor(s) and which will be provided by the facility construction contractor.

Figure 14 shows the basic control and data lines within and between subsystems. The dashed boxes outline procurement or vendor responsibilities. Lines which cross these boundaries interconnect signals between different vendors and require detailed interface specifications prior to final design and procurement. The existing functions at AEDC and NASA are noted.

3.3.1 Photon Source Instrumentation

The source vendors will supply all of the hardware required for instrumentation for the x-ray sources. All control and timing equipment, electrical measurement equipment, and fault location diagnostics and processing equipment will be designed, built, and supplied by the vendors. Remote-control hardware for sources will be provided by the source vendors, but will be incorporated into the source subsystem control console. X-ray firing switches and critical source status information displays will also be provided by the source vendors to be incorporated into the facility test operations console.

Electrical data on individual modules and timing subsystems which are used by the vendors to evaluate source operation and to identify fault or maintenance requirements will be made available to the facility data subsystems, where it will be used for long-term trend analysis. Any critical safety or emergency action control functions which the source vendors or the facility designer identify will have the capability of being activated by the facility central computer. Appropriate sensor and interlock signals used in identifying these emergency actions will also be made available to the facility data system. Software and appropriate electrical driving circuits to actuate emergency-action functions will be developed and provided by the facility construction contractor.

A conceptual block diagram of the photon source instrumentation and control configuration is shown in Figure 15. It should be noted that, due to the great quantity of data expected from the MBS, all measurement and diagnostic equipment is self-contained in the vendor equipment. It appears reasonable that the facility high-frequency data links

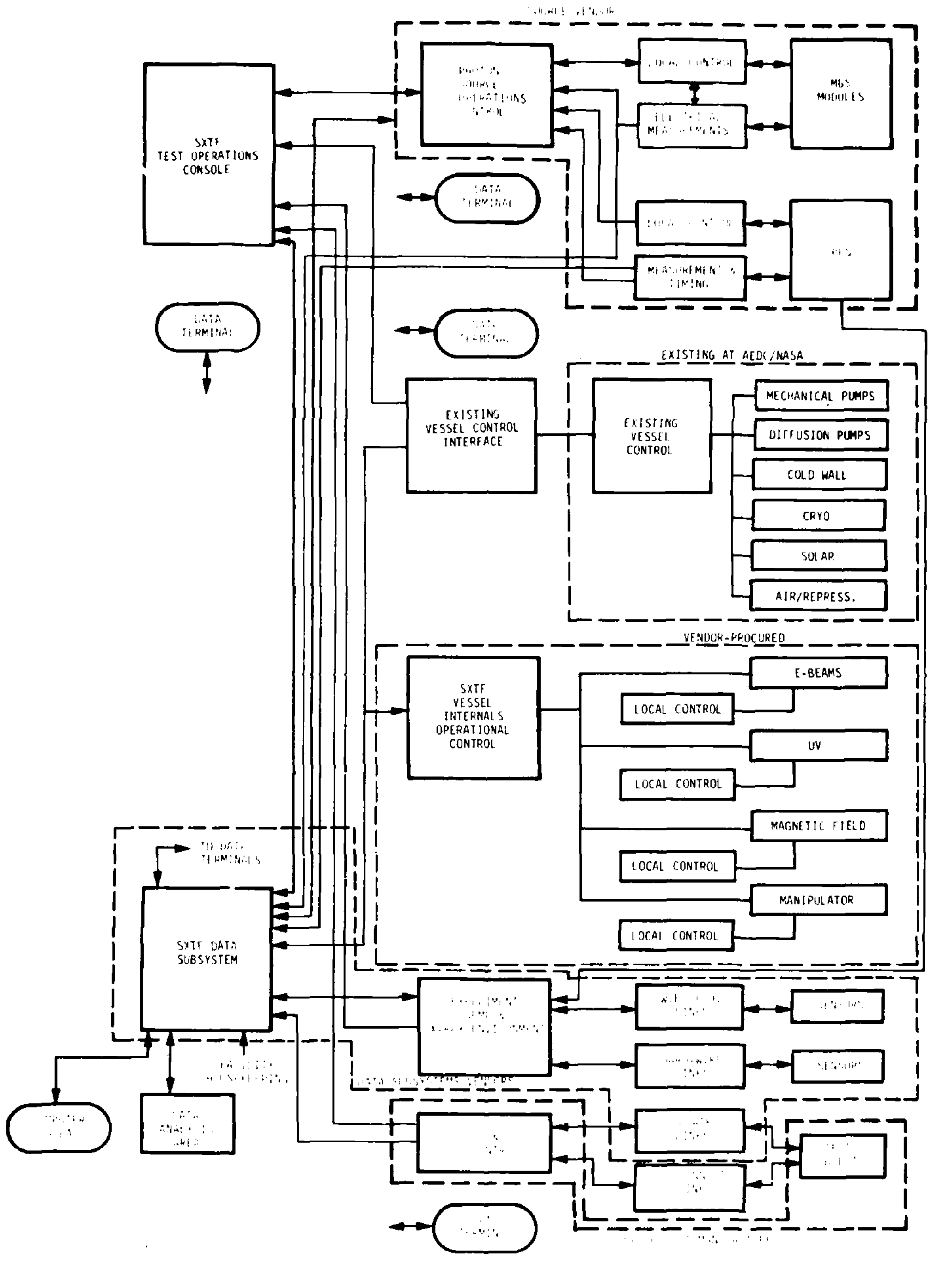


Figure 14. SXTF data/control flow and interface lines

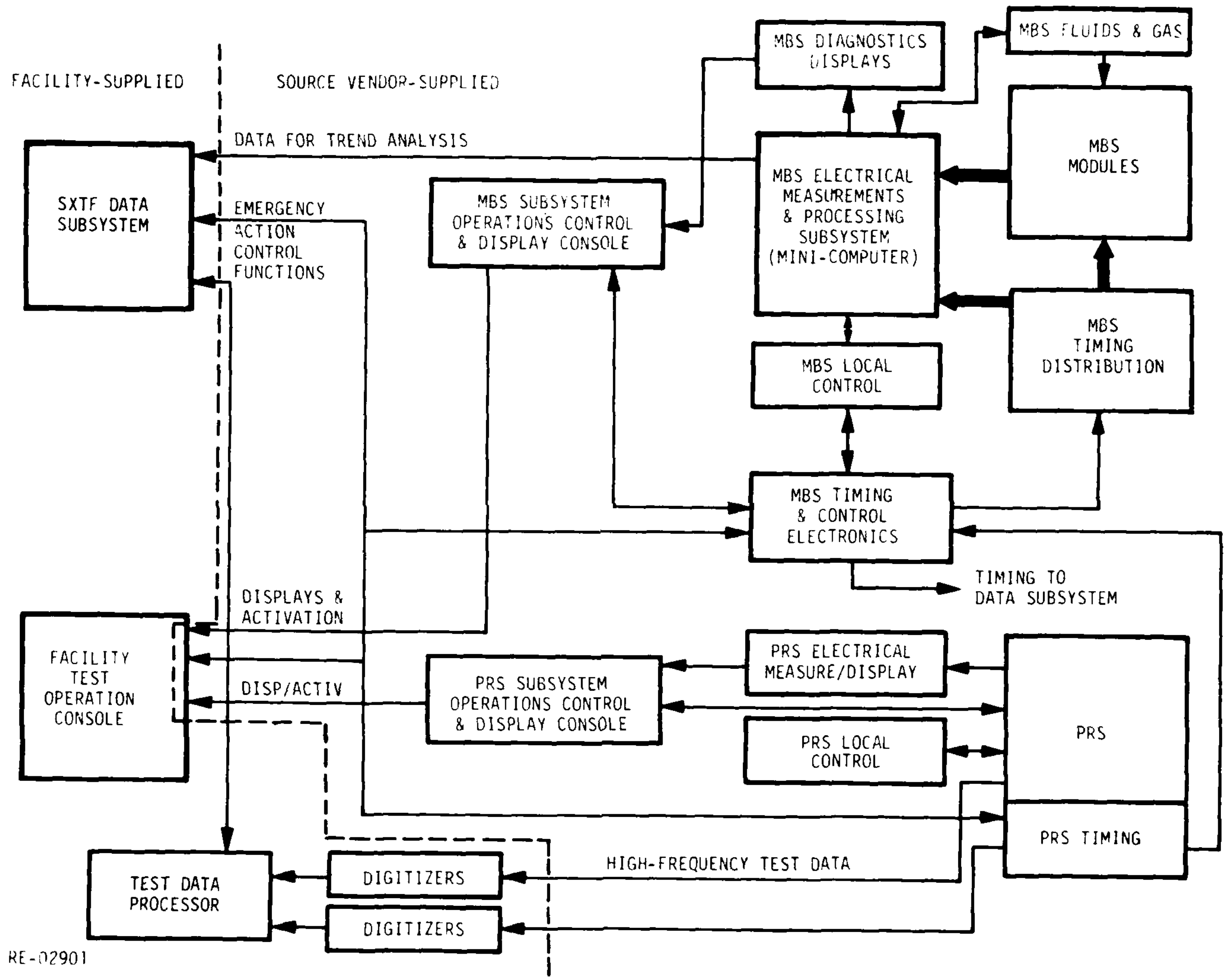


Figure 15. Photon source instrumentation and control diagram

and digitizing capability be made available for evaluation of the PRS, assuming that only a few data points need be measured under typical operating conditions.

The concept design shows two separate electrical measurement subsystems, since they are separate functions. Depending on the nature of the procurement contract and the assignment of primary source responsibility between the MBS and the PRS, it may be possible that the electrical measurement and processing electronics (minicomputer) that is probably necessary for MBS diagnostics and maintenance could also be used for the electrical measurements evaluation of the PRS.

3.3.2 Vacuum Chamber and Internal Subsystems Instrumentation

The devices and subsystems associated with the vacuum chamber can be grouped into (1) the existing equipment associated with establishment of the vacuum environment and thermal conditions of the test object, and (2) those new tank internal subsystems which create the proper x-ray test environment. Figure 16 is a block diagram of the tank and internal subsystem interfaces.

Items associated with the first group are the mechanical roughing pumps and high-vacuum pumping equipment and associated refrigeration equipment of the cold walls and cryogenic pumps. There is also, within this group, equipment required to re-establish the normal atmosphere in the chamber and to maintain the proper temperature and humidity in the tank during non-vacuum periods. These items currently exist at both the AEDC and NASA facilities. Only key status information and critical control functions will be directly provided to the SXTF facility test operations console. Critical or emergency action control functions will be made available for automatic computer control.

The second category of equipment provides for test object suspension and translation and maintenance structures associated with spacecraft insertion into the tank and the repair and maintenance of the photon source components which are internal to the tank. The mechanisms associated with these devices will be operated from convenient locations near the tank, and lockout or inhibit controls will be made available to the test operations controller and to the spacecraft test manager in the AGE area (and, if appropriate, for emergency action control by the computer).

The second category also includes equipment identified as the tank internal subsystems, and includes materials and equipment associated with the electromagnetic and electrical control of the environment inside the tank which creates the proper simulated test conditions. These subsystems include the EM damper, the electron backscatter

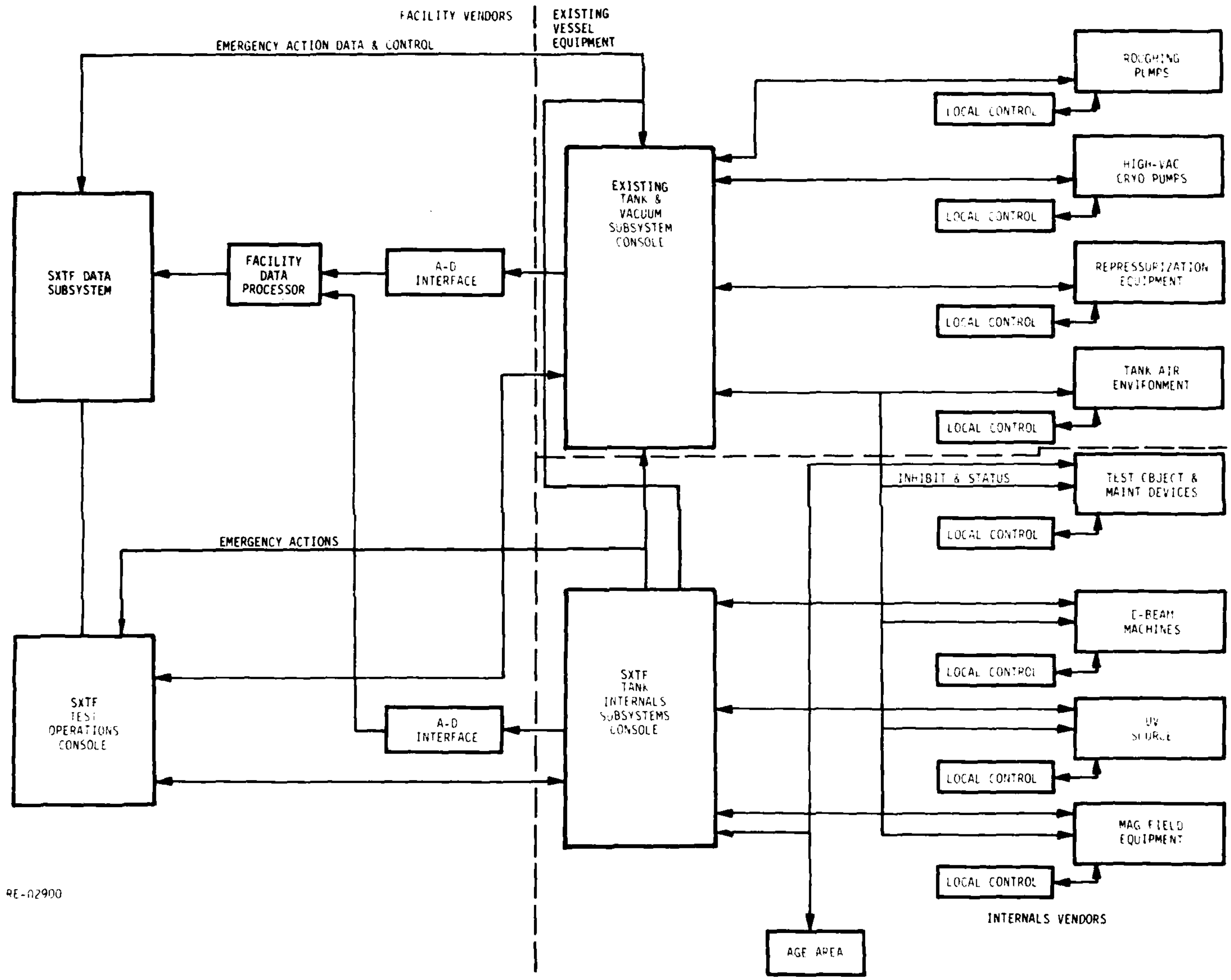


Figure 16. Tank and internals subsystem instrumentation diagram

materials, the electron beams used for spacecraft charging, any ultraviolet light sources used to create differential charging conditions, and (possibly) magnetic field suppression coils.

Each of these tank internal subsystems is probably procured from separate vendors, and where appropriate, local and remote control functions should be required. As previously described, any emergency shutdown or control functions shall be capable of being activated under computer control and on the SXTF operation control console.

3.3.3 X-ray Response and Environment Instrumentation

The equipment associated with measurement, transmission, recording, and processing of the electrical response data from the test object and with determination of the x-ray environment inside the test chamber includes:

- Sensors: $\dot{B}$, current, voltage, etc.
- Data links: isolated fiber optic links to the test object and hardwire links to tank environment sensors
- Data recorders: programmable waveform digitizers, Tektronix model 7912
- Data processing: waveform analysis
- Data display: CRT quick-look and hard-copy printouts
- Calibration and timing equipment

The basic features of the data-recording subsystem are shown in Figure 17. The SXTF wideband data subsystem is an integrated data system which consists of fiber optic links and digitizing recorders. A capability of operating up to 50 links is included in the design; probably 15-25 will be in the initial operation. It is intended to place the switching, calibration, and mode control of the data links and data-recording equipment under computer control since this is an existing and most desirable feature of the data digitizing equipment.

A most important element of the data measurements capability of the SXTF is the fiber optic link equipment used to maintain isolation between the test object and the surrounding conducting surfaces. A brief discussion of the fiber optics considerations and concepts is presented below.

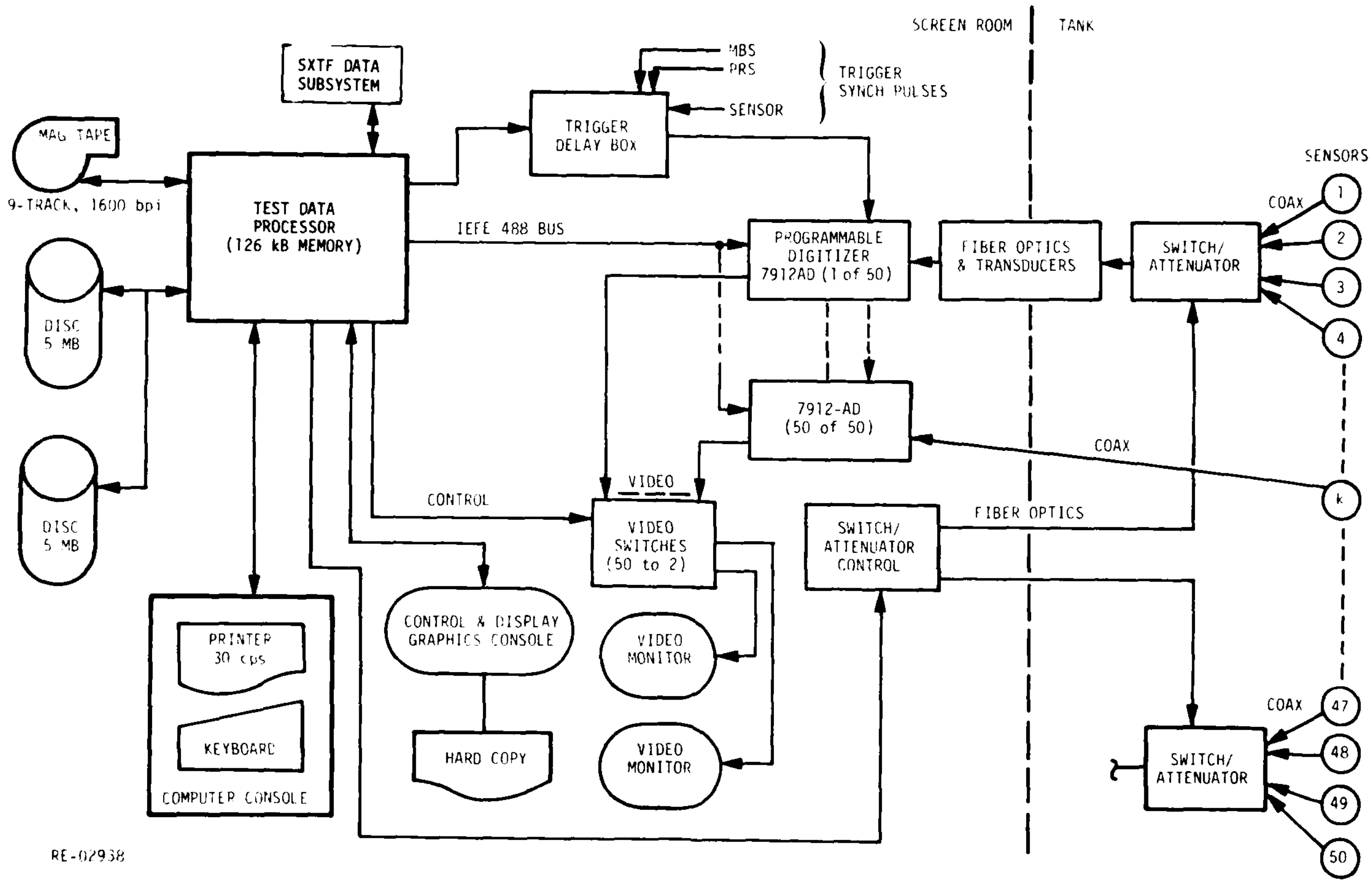


Figure 17. Radiation environment/SGEMP signal processing system block diagram

Fiber Optic Links for SXTF

Fiber optic links have many inherent advantages for performing the electrical isolation function. They are relatively immune to electromagnetic interference (EMI), and the dielectric nature of the fiber cable eliminates the instrumentation problem of ground loops and crosstalk between cables. The basic limitation of fiber optic links for the SXTF relates to the effects of high-level radiation in the form of x-ray pulses and electrons on the electronic components and the fiber optic cables which comprise the link. The radiation environment can cause the components to degrade during the period of exposure. The cables themselves will darken and then recover to a certain extent, but there is also some long-term darkening. This exposure degradation appears to be the primary developmental requirement for the design and application of fiber optic systems for use in the SXTF.

Fiber optic links could be used in a number of applications at the SXTF. The response measurements application requires that some links maintain operation during the pulse. Other links would not have to operate during the x-ray pulse, but would have to survive the pulse and return to normal operation (recover) rapidly after the pulse. Links with this requirement provide health and status information on board the spacecraft, and provide control signals from the ground equipment to the spacecraft.

Simplified block diagrams of these two categories of fiber optic links are shown in Figures 18 and 19. References 5 and 6 provide preliminary specifications for the technical features of these links and identifies parameters relating to x-ray environment, electrical characteristics, and reliability.

Wideband Data Processing

The output of 50 programmable digitizers (7912 AD) is transferred in a selectable sequence to the test data computer, which performs a number of functions in additio to data manipulation. The computer will control trigger and time marks used to initiate digitized waveforms, and will be used to control the pre- and post-test calibration of the links. As shown previously in Figure 17, the test data and digitizing equipment will include video monitors which can be selected to monitor any one of the 50 digitized signals immediately after a test x-ray exposure.

It is intended to obtain as much standard software as possible for performing data analysis functions and to utilize off-the-shelf computer hardware whenever possible.

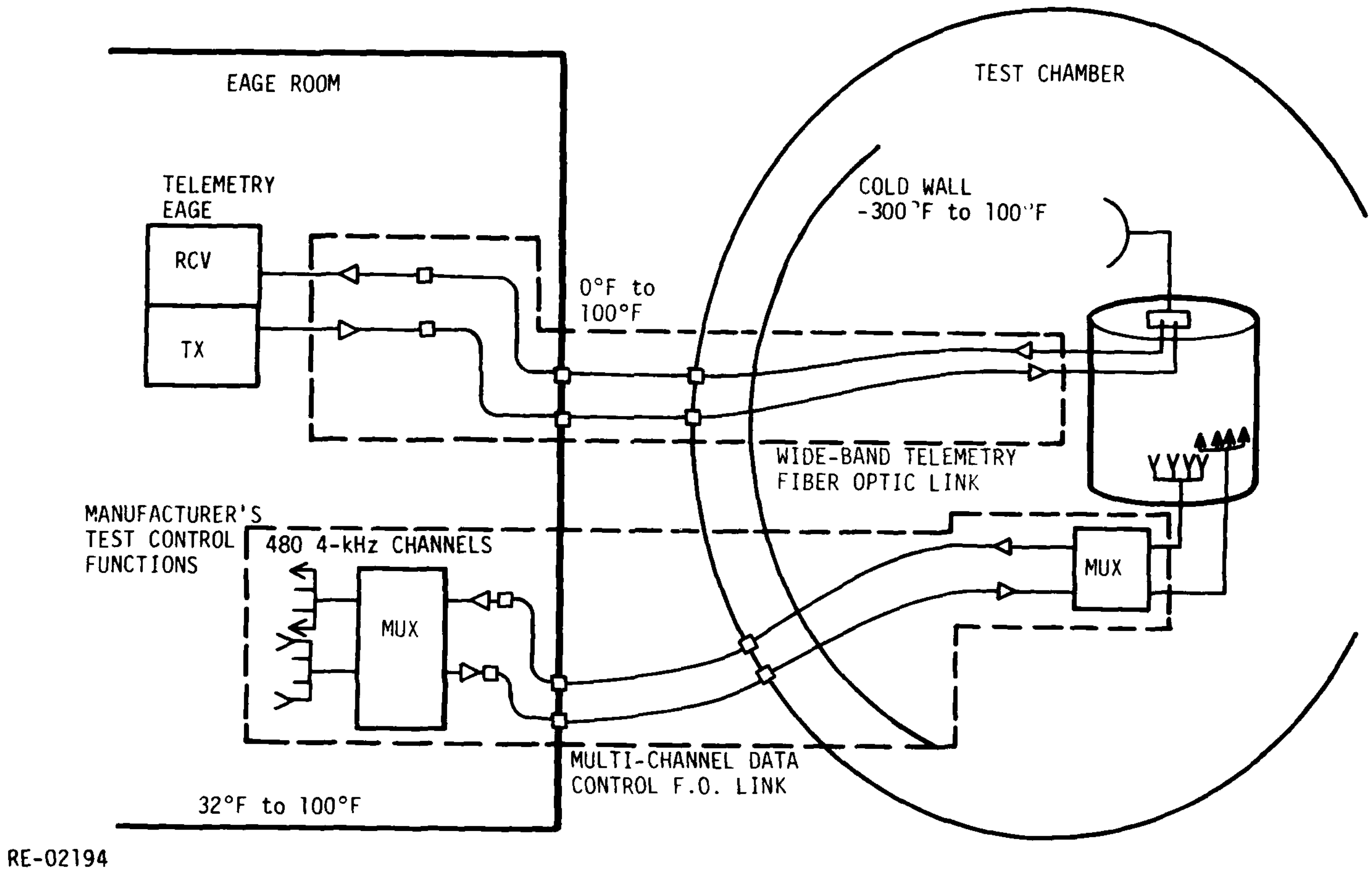


Figure 18. Telemetry and test function, two-way data links

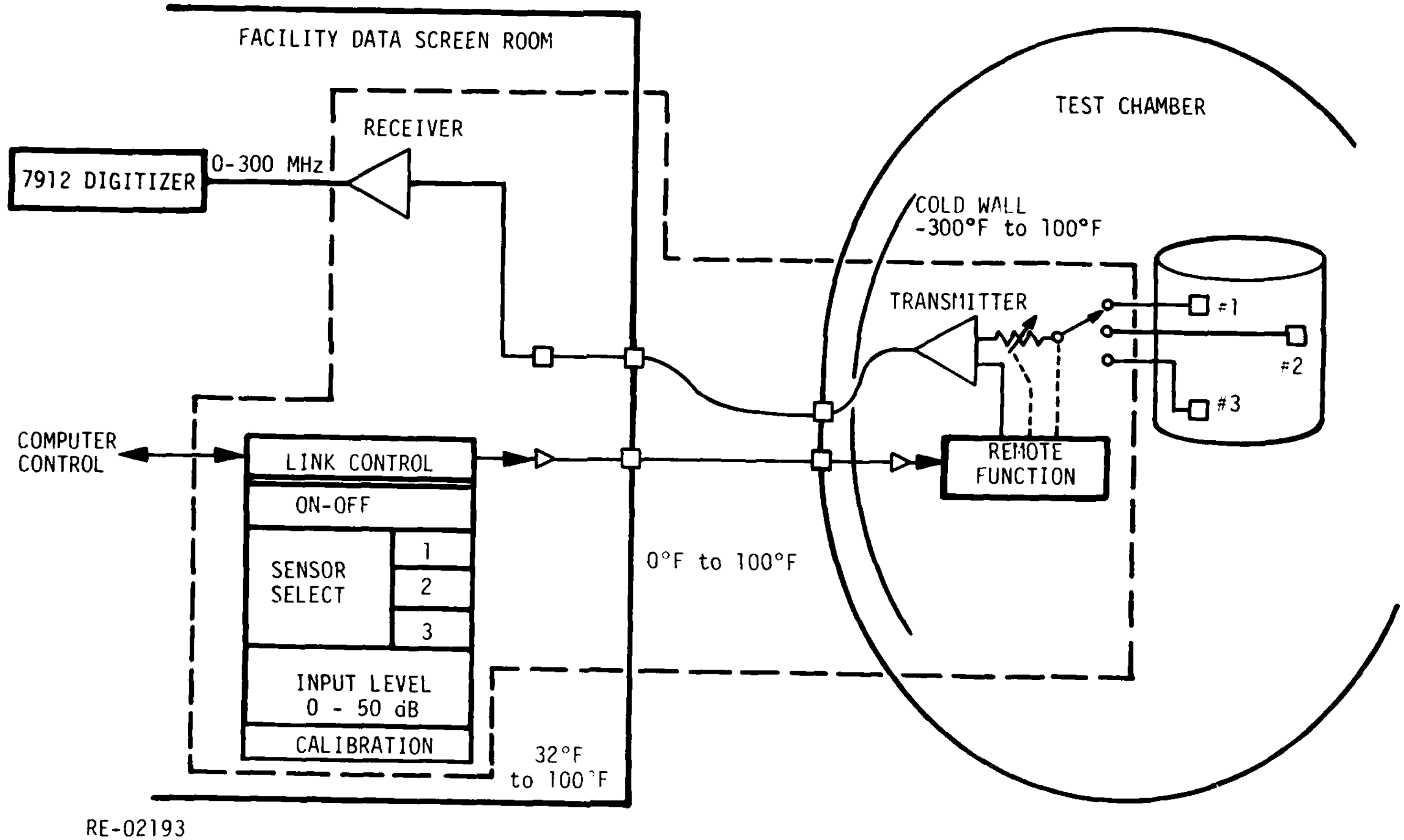


Figure 19. One-way wideband data link

3.3.4 Facility Computer Subsystem

The primary function of the facility data subsystem is to record, process, and display SGEMP data and to control the data collection equipment. Other than the central computer processor, the equipment to perform this function was described in the previous subsection. A computer system with this capability can also be used to perform many other functions. Secondary functions anticipated for the facility data subsystem include performing photon source trend analysis based on electrical data provided to the central computer system from the data subsystem of the photon sources. The central computer system can also provide many monitoring, recording, and display functions for the subsystem controllers in the form of CRT displays, printout of check lists, alert signals, flow diagrams, and guidance in the sequencing of complex operational activities.

Another important function which the central computer facility can perform is the monitoring and activation of emergency (control) and safety (inhibit) action circuits to selected operational subsystems designed to protect personnel and equipment from dangerous or costly events which might go unnoticed by human observers or which might require rapid evaluation and comparison of a number of events that could lead to a dangerous situation.

A computer can perform auxiliary functions relating to historical record keeping and data comparison processing useful to test analysis and unusual event evaluation. It can also perform general housekeeping functions such as security checks, quality control, routine and preventive maintenance schedules, and check lists for periodic activities. To perform these functions, the facility central computer will receive inputs from a number of facility subsystems. From the photon source area, the central computer will receive and process the MBS electrical data. From the vacuum chamber and tank internals subsystem, it will receive selected analog and digital signals. Critical points in each subsystem will be monitored and input to the computer for continuous evaluation for activation, under computer control, of emergency action or inhibit controls. The central computer will also receive and process the data from the 50 programmable digitizers and will format and display results as required by the test analysts.

The general configuration of the facility data-processing subsystem is shown in Figure 20. A central computer processor provides the high-volume recording and processing functions, and several minicomputers handle simpler operations in each subsystem control area. A variety of bus structures can be handled with RS-232, IEEE 488, and

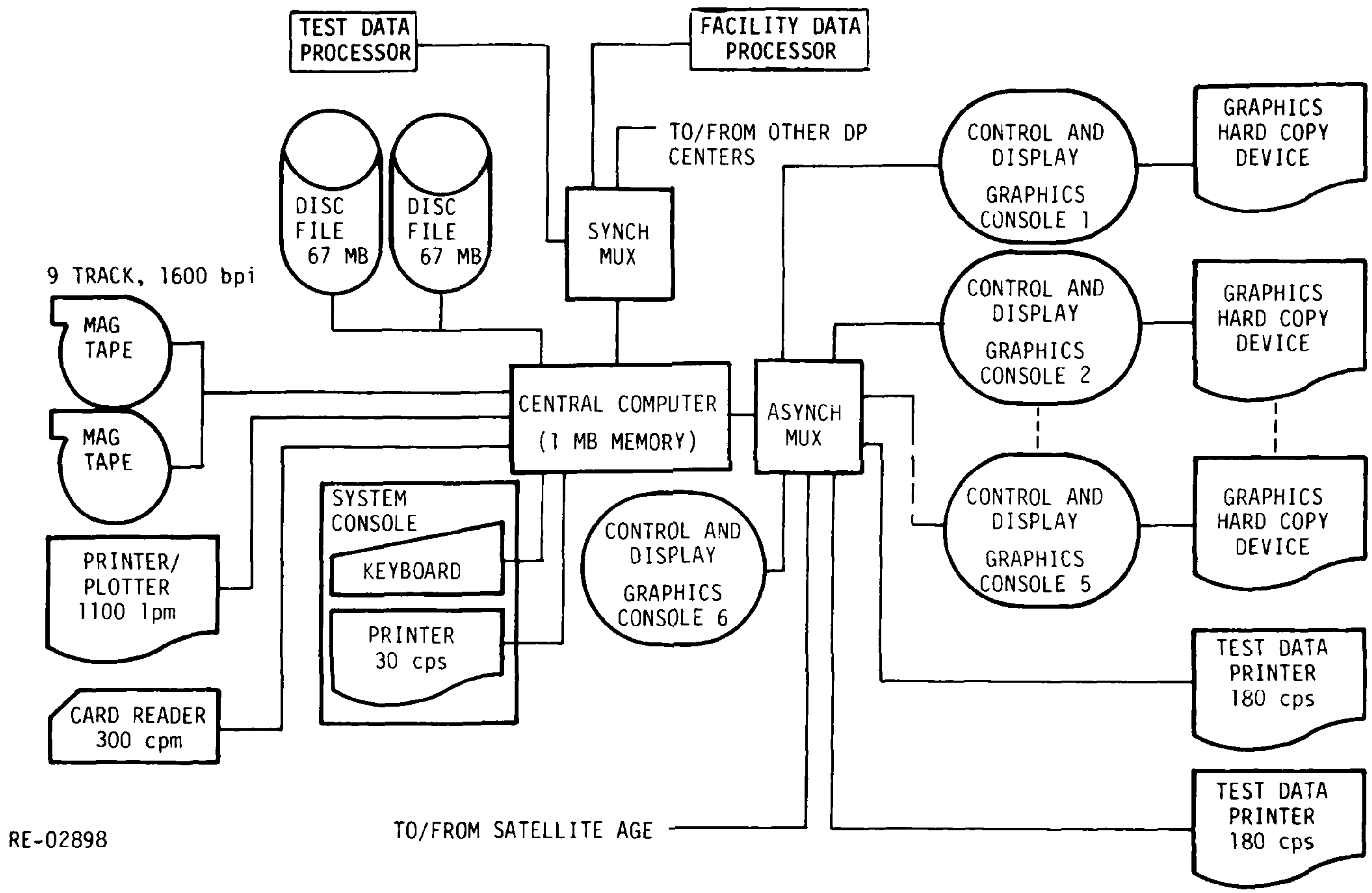


Figure 20. SXTF data subsystem central computer block diagram

special-purpose A-D converter interfaces applied to effectively interconnect data input and control outputs with the facility subsystems.

Data, display requests, and processed outputs can be made available to almost any part of the facility through the use of facility-provided CRT terminals. The reference design has six such terminals, although this number can be expanded with the purchase of additional units. It is proposed to provide terminals at the following locations.

1. Facility test operations control console
2. Tank internal subsystem control area
3. Photon source operations area
4. Spacecraft manufacturer's operations area
5. Experiment data-recording area
6. Central computer equipment area

Through software control, any CRT terminal in the facility can be set up to perform data and display functions for a specific purpose. For example, after a test operation, the terminals used to assist operations controllers in the performance of sequencing and monitoring equipment could be used by an SGEMP analyst to evaluate digitized data from any one of the 7912s.

3.4 INSTRUMENTATION SHIELDING AND GROUNDING

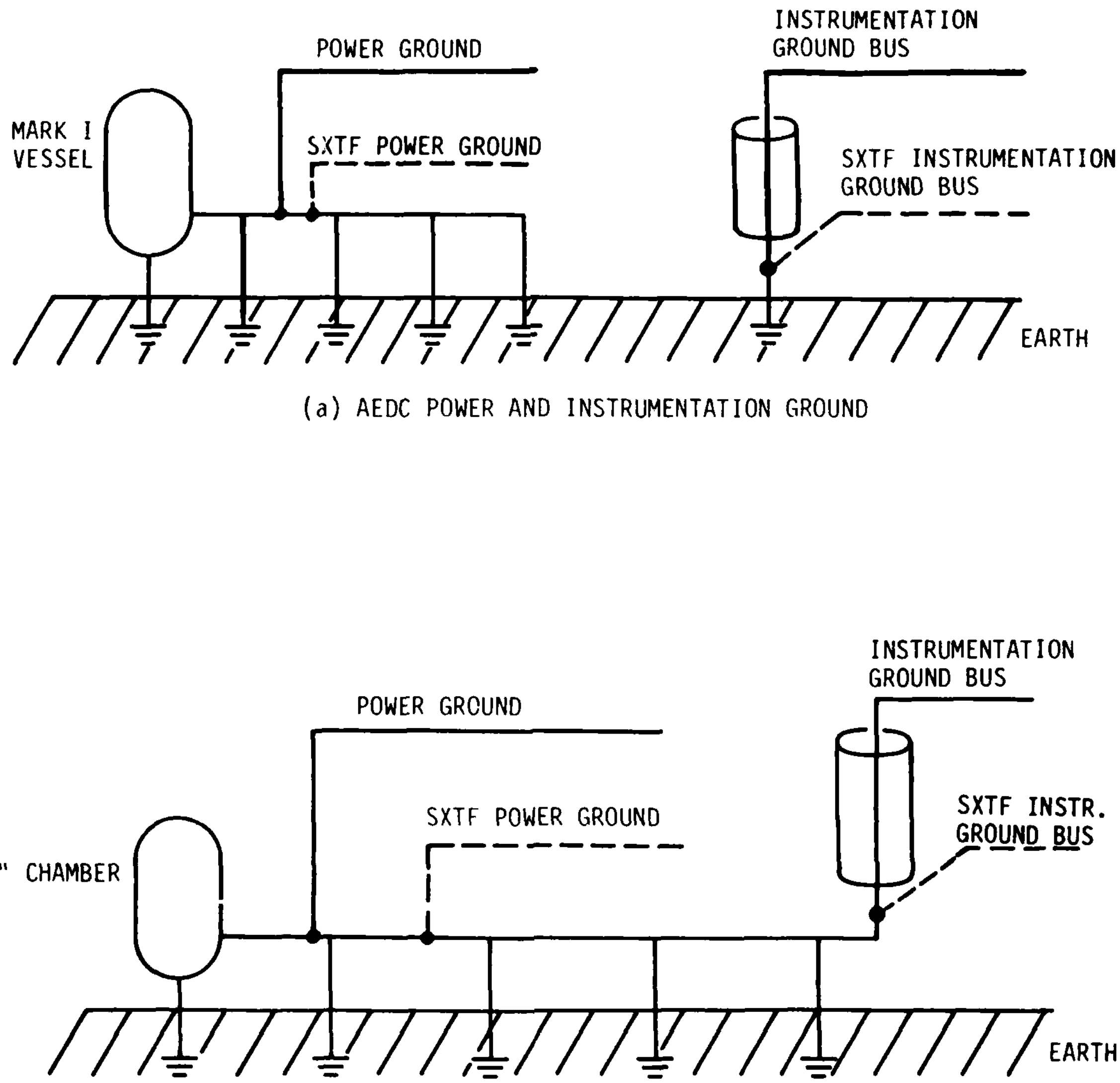
The new structural RDT&E building covering the photon source will provide for five RF screen rooms to house control, instrumentation, and data subsystems associated with SXTF tests, and provide space for the spacecraft manufacturer's system checkout equipment and interfaces with the SXTF data system. At both AEDC and NASA, these screen rooms are structurally interconnected on three floor levels. Each screen room will be tied to the vacuum vessel through a large (2 x 3 ft) duct used to shield all interconnecting cables, and all the screen rooms will be electrically interconnected to each other.

SXTF operations will be functionally connected to the existing vacuum chamber controls, and both AEDC and NASA have ground systems to which their power and instrumentation systems are attached. The techniques used at AEDC and NASA for instrumentation grounding differ slightly, requiring that SXTF instrumentation be properly integrated into the selected site.

At AEDC, the building or power ground system consists of a buried grounding system to which all metallic structures, including the vessel, and all AC power grounds are connected. The AEDC instrumentation ground is separately buried and isolated from the power ground system. The separation is carried all the way to the instrumentation and control equipment on the upper floors of the Mark I building via an insulating pipe. Analysis and evaluation of this instrumentation ground and the final design for interconnections between existing AEDC control/instrumentation and the new SXTF control/ instrumentation will have to be performed to determine if the SXTF should tie into the present instrumentation ground or whether a new and separate SXTF instrumentation ground system should be included in the RDT&E construction.

The NASA ground system consists of a massive ground plane built into the foundation of the high-bay, to which both the "A" and "B" chambers are attached. The existing NASA instrumentation ground system is also attached to this basic ground plane, but is isolated from the power and structural ground as it is routed to the control and instrumentation rooms on the second floor of the building. A decision to integrate the SXTF instrumentation ground into the existing NASA instrumentation ground or to construct a separate and isolated SXTF instrumentation ground will have to be made based on the nature of the NASA/SXTF instrumentation interfaces and on any unique SXTF instrumentation requirements.

Figure 21 illustrates the basic difference between the AEDC and NASA ground systems, and suggests a likely SXTF interconnect to them. It appears reasonable at this time to base SXTF instrumentation grounding on the existing grounding scheme used at the respective candidate sites.



(a) AEDC POWER AND INSTRUMENTATION GROUND

(b) NASA POWER AND INSTRUMENTATION GROUND

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Figure 21. Grounding schemes

4. MILCON DESCRIPTION

The MILCON design effort addresses those parts of the SXTF program that will be built under a military construction funding program. This part of the procurement will be based on a new MILCON final design. The requirements described in the following subsections address floor space and functional features necessary in support of x-ray tests.

The original reference design (Ref. 1) described a MILCON structure containing all administrative, laboratory, maintenance, instrumentation and control, and satellite preparation areas needed in support of the vacuum chamber operation and satellite testing. Approximately 40,000 sq. ft. (1000 m^2) of floor space was included in this design.

Incorporating the SXTF into an existing facility such as AEDC or NASA dictates that many of the functional areas previously in the MILCON structure be integrated into the modifications of the existing structure. These areas primarily include RF screen rooms, data subsystem and analysis areas, and source maintenance and laydown space. It also appears reasonable to utilize existing office and laboratory space at the candidate sites (where it can be made available for SXTF functions), and to use some of the added space created by the RDT&E structure that encloses the new photon sources into an existing chamber building. Therefore, the availability and use of existing or newly created space for SXTF functions previously included in the original MILCON structure will alter the requirements or and the size of any MILCON built at either AEDC or NASA.

A general comparison of the original MILCON functional space requirements and a revised estimate of space needed for functions not previously included in the RDT&E structures is shown in Table 3. Figure 22 shows a floor plan layout indicating one possible design concept for a new MILCON structure. The structural shape can be modified to suit the site. A two-story building is shown which includes a satellite pre-assembly high-bay to augment the satellite assembly space that is an existing part of the AEDC Mark I or use of the large high-bay between the NASA "A" and "B" chambers. Incorporating the SXTF into an existing operational space simulation facility that already has laboratory and shop facilities available for normal space chamber operations may negate the need for separate or new SXTF laboratory and technical support functions. Final determination of the need for or size of a new MILCON project will depend on site selection and on the final determination of available existing facilities for SXTF use.

Table 3. MILCON Functions/Space

Function	Original MILCON Requirements	Equivalent or Greater Space Now in RDT&E	New MILCON
Office	(15-20) 4000		(12) 2200
Conference, main	600		1500
High-security	200		500
Labs, electrical	2000		2000
Checkout/assembly	2000	X	
Data	1500	X	
Sensor, dosimetry photo	1500		2000
Machine shop	1000		1200
Instr/control screen room	2500	X	
Satellite preparation*	5000	X	2200
User AGE and support	1500	X	
Lobby (see crypto)	500		1200
Building utilities/halls	17700		7200
	40,000 sq.ft.		20,000 sq.ft.

*A smaller satellite preassembly space is provided in the new MILCON.

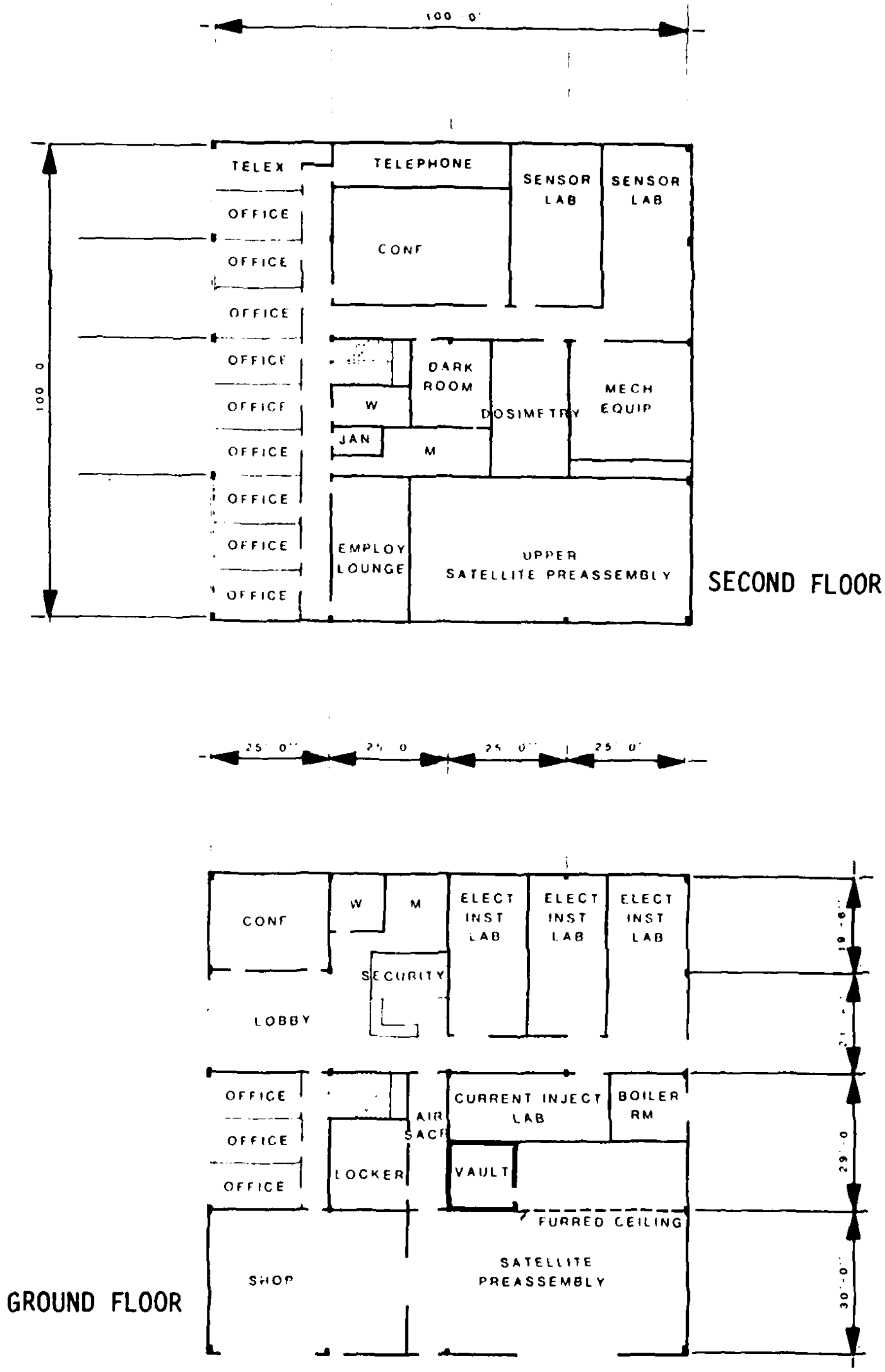


Figure 22. MILCON floor plan

5. TEST OPERATIONS AND FACILITY REQUIREMENTS

This section addresses the general concept of test operations envisioned at the SXTF and includes brief discussions of other related staffing, safety, and management aspects of SXTF operations.

5.1 TEST PROGRAMS AT SXTF

The basic purpose of the SXTF is to perform full-system tests on military spacecraft to determine their response to x rays. These tests would be performed in response to the survivability criteria specified for a military satellite and would be in support of the overall hardness qualification of the satellite. Such tests would be conducted by the spacecraft manufacturers under the direction of the government procurement agency. Other types of SXTF test activities would include spacecraft development and design verification tests, operational test and evaluation programs, phenomenology tests, and tests to improve the capability of the simulation facility itself.

A brief summary of the characteristics of each of these types of tests is presented in the following paragraphs.

5.1.1 Spacecraft System Tests

These tests are primarily intended to verify the analysis of the response of a radiation-hardened satellite to a photon exposure. Under the direction of a military spacecraft procuring agency such as SAMSO, the spacecraft manufacturer would design and conduct the test at the SXTF, following a test plan developed in consonance with the engineering and operations staff of the SXTF.

There would be a desire to complete the tests rapidly. The test article (qual model) would probably be in the test facility from one to two months, and it is possible that some testing would have to be conducted on a 24-hour/day, 7-day/week operation. Predetermined critical spacecraft operational modes would be tested using maximum x-ray exposure. All spacecraft subsystems should be operational during the tests.

Wide-band SGEMP test data and normal spacecraft telemetry and spacecraft operations data would be evaluated using quick-look methods before each sequential test is initiated. Thermal and vacuum environment provided by the facility would be continuously monitored by the tester and subject to his requirements.

Successful test operations would require a minimum set of quality test data collected within a defined maximum period of time. The Test Director (SAMSO) would review test results and determine the adequacy of the test data, based on established criteria.

5.1.2 Spacecraft Development and Design Verification Tests

These tests would be conducted during the early design and fabrication phases of a satellite program, and are intended to ensure that the technical approach and materials used in a spacecraft satisfy the design requirements. The test program could extend over a few months to possibly half a year, and would probably be a one- or two-shift operation on a 5-day/week schedule. A variety of tests and test item configurations would be used. The testing sequence would be dependent on the results of previous tests.

Information from these tests would focus on cause and effect, and variances from calculated values would be of significance. Some tests probably would use only part of the photon source, and test objects would range from full-scale mockups to small subassemblies tested at very near-in positions.

5.1.3 Operational Test and Evaluation Program

The "op-eval" is a series of tests on a production item test article which thoroughly evaluates the capabilities and features of the equipment. For a military spacecraft, these tests would probably be conducted on a future flight model and would be conducted over a specified period, possibly three to four months. Many different spacecraft modes of operation would be tested. Tests would initially be done at very low levels, with the source intensity increased to some maximum level. Since these op-eval tests do not affect any production program schedule, the major cost would be in the test crews and test site personnel. To reduce time on site, it is likely that a two-shift operation would be considered. The primary test data would focus on operational effects on the test object.

5.1.4 Phenomenology Test Program

As the name implies, these tests would investigate scientific phenomena, and could range from experiments investigating materials to tests which validate analytical predictions.

Tests would normally be conducted on an as-available schedule, and might last from a few weeks to a few months. Unless some particular urgency were identified, these tests would probably have numerous short test periods broken by analysis or evaluation periods. Data requirements would be tailored to the specific needs of the experimenter.

5.1.5 Simulator Research and Development Program

As experience is gained and new technology develops, the capability and characteristics of the simulator should be improved to provide higher-quality simulation and more efficient test operations.

The staff at the SXTF should continuously evaluate the capability of the facility and investigate ways to improve it. They should be aware of outside research which might be applicable to upgrading the facility, and time and effort should be spent by the facility engineering staff on research and experiments intended to improve the photon source, the tank internal subsystems, and overall test operations.

5.2 X-RAY EXPOSURE ESTIMATES

Estimating the number of 'firings' of the x-ray sources at the SXTF involves consideration of both equipment technical capabilities and expected test operational limitations. Estimates of source utilization are necessary because:

- Upper limits on the number of MBS pulses and electron charging events in a quarter, and in a year, are required for radiation safety design and personnel protection.
- Anticipated weekly, monthly, and annual usage of the radiation source and the other equipment (e.g., vacuum system cycles) is required to determine lifetime needs for the various subsystems.

The two sets of numbers may differ considerably. In general, the utilization rates will vary greatly, depending on the type of operation in progress. For example, the MBS bank used for phenomenology or TREE testing could be pulsed many times per shift; a complex satellite system test using both sources may involve only a few exposures a day. On occasion, a number of pumpdowns may be required during a test program; other programs may have the test object remain in the tank unchanged for several weeks.

The following discussion provides an estimate of the number of x-ray 'shots' which could be performed during SXTF operations. Two factors to be considered in these estimates are (1) the basic capability of the x-ray machines and (2) the reasonable rate at which test operations are likely to be performed.

The SXTF will be capable of creating three threat environments:

1. The MBS
2. The PRS
3. Electron beams

A test involving the combined MBS and PRS sources would probably schedule four x-ray exposures in one working day. It might be possible to create an electron plasma environment for each of these exposures, but the additional complexity would reasonably limit the schedule to more like two exposures in any one day.

As a shared facility, the SXTF capabilities for either AEDC or NASA would possibly be used for one or two major test programs in one year. Preparation for a test program (ship equipment, prepare and check out the test object, plan for tests, develop and prepare test procedures, etc.) requires much more time than the few weeks in which the actual x-ray exposures occur. Therefore, the number of test exposures which can occur during any one calendar quarter or in a year are appreciably less than the simple addition of expected daily or weekly exposures.

Table 4 provides a summary of estimated x-ray shot rates. An indication of possible maximum short-term rates and more typical maximum average rates are shown. The high-voltage operational mode of the MBS places much greater stress on the machine insulators and diodes. The shot estimates, therefore, indicate that, although any combination of 100- and 200-kV modes may be used in a test, it is unlikely that both the low- and high-voltage rates would occur over any one quarter or year.

As presently foreseen, after a few hundred shots it will probably be necessary to enter the vacuum vessel to perform periodic maintenance. This action could include replacement of debris shield material, cleaning of insulators, and replacement of source components. Dependent on the failure characteristics and normal life of photon source components, it may be desirable to refurbish all elements at one time to bring the source up to a 'zero-time' condition prior to a major SXTF test program. Time required to perform such a task is presently unknown but, with a 200-module array, could range from a few weeks to a few months.

5.3 ILLUSTRATIVE TEST PLAN AND SCHEDULE

The fundamental purpose of the SXTF is to perform a full-system x-ray test of an operating military satellite. The following illustrative test plan is presented to identify

Table 4. Summary of X-Ray Shot Rates

	Shots/Day		Shots/Week		Shots/Qtr		Shots/Year	
Source	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.
MBS								
100-kV	20	4	100	20	250	100	500	200
200-kV	10	2	50	10	100	50	200	100
PRS								
Wire	4	4	20	20	100	50	200	100
Puff	10	4	50	20	100	50	200	100
Electron Chargings	4	2	10	5	25	10	50	20

the anticipated test operation required to perform such a test and to supply insight into the sequence and schedule for such a test. A report by TRW (Ref. 8) summarizes spacecraft manufacturers' test planning activities. Considerable information on test requirements, sequences, and schedules from the spacecraft manufacturer's point of view is extracted from that report and used along with additional requirements based on consideration of the needs of the facility operator and of the experimenter.

5.3.1 Test Organization

A typical test organization chart is shown in Figure 23. The test planning organization would develop the general requirements and schedule for the test and would address the management responsibilities between the spacecraft procuring agency (e.g., SAMSO), the spacecraft manufacturer, and the test facility manager (DNA and test site). The test requirements and objectives would be documented. Schedules, support services, and overall test concept are developed many months before the actual test preparation and operations are performed.

The "in-chamber" test organization (Figure 23) consists of on-site personnel who will run the test. The general test requirements and plans are expanded into detailed test procedures, checklists, and sequences. The two principal parties in actually performing the SXTF tests are the spacecraft manufacturer, who sets up the test object and prepares and analyzes test data, and the facility test operations controller, who ensures that all environmental and facility service conditions are in accordance with the previously specified ranges and, in coordination with the spacecraft test manager, intiates the x-ray exposure sequence.

The Test Director will oversee this operation and will be the final reviewer of test results to determine the need to repeat a test or to advance to the next phase of testing, on the basis of the sufficiency of the test data to satisfy test objectives.

5.3.2 A Minimum-Level System Test

TRW describes a minimum-level system test and identifies its objectives:

1. To evaluate the system models used to develop the hardened design.
2. To evaluate active system response to the simulation exposure level.
3. To evaluate data for hardness assurance.
4. To evaluate in-plant test levels.

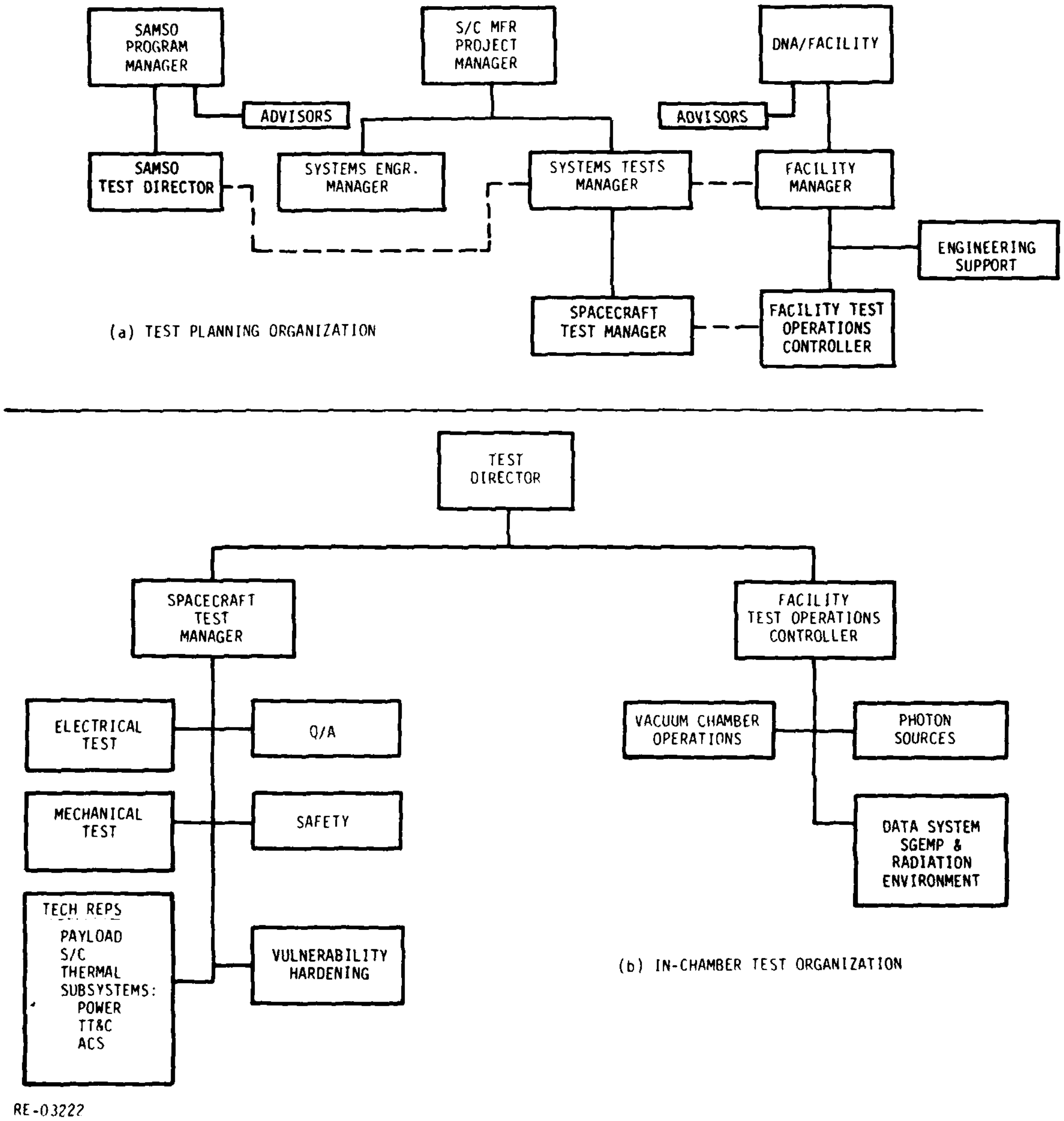


Figure 23. Spacecraft qualification test organization

Obviously, many measurements would be desired to give good model verification. Obtaining data from all parts of the spacecraft and from all cables is not possible, and the question of just what and how many measurements should be made is a difficult one. The following measurements constitute a minimum set suggested by TRW.

10	Cable bundle measurements
25	Individual wire current measurements at one connector
20	Individual wire measurements, 5 per connector at 4 connectors
2	Solar array boom current measurements
1	Solar array power cable bundle measurement
4	Solar power cable individual wire current measurements
4	E-field measurements - 2 external, 2 internal
4	H-field measurements - 2 external, 2 internal
70	

Two test object orientations are proposed. The "broadside" orientation for a reference test satellite such as FLTSATCOM or DSCS would have the antenna facing the x-ray source. An "end-on" orientation is also suggested. All the measurements identified above should be taken in each orientation. In these orientations, the satellite would be exposed to the full combined PRS/MBS spectrum.

Satellite exposure at levels higher than at the 7-m (tank center) location is also considered desirable in a qualification test, and it is suggested that a "close-in" MBS exposure of both the top and bottom of the spacecraft be performed.

A third consideration in defining a test configuration is selection of the appropriate operational mode in which to operate the satellite during each test. Combinations of AVCS, power, TT&C, and payload (e.g., communications package for FLTSATCOM or DSCS) can be matrixed to be in any one of many modes of operation. In defining a minimum test program, TRW indicated that probably one major mode might be identified and selected as a result of analysis and previous in-house testing. Two or more critical modes would, of course, add to the test schedule accordingly.

The SXTF test shot matrix for a test satisfying the previously described requirements is shown below.

Spacecraft Position	Source	Orientation	Test	Good Shots
Center of tank, ~7 m	PRS-MBS	Broadside	EM response	4
		End-on	EM response	4
Close-in, ~2 m	MBS	Broadside, top	EM response	20
		Broadside, bottom	Active response	20
				48

The data equipment assumed available for this test is as shown below.

20	7912 fiber optic test data links
4	7912 radiation environment data links
1	7912 PRS data link
25	7912 digitizers

Fiber optic links are assumed to be capable of remote switching to any one of four sensor inputs. Data from 7912 digitizers is transferred to central data storage within minutes of data acquisition. Quick-look data processing to obtain basic waveshape, peak values, and envelope power for 25 measurements can be done and displayed (CRT or hard-copy print-out) in 30-60 minutes.

Figure 24 shows a test schedule from Reference 8 defining the time needed to perform a test, excluding the actual x-ray testing, from the time the manufacturer's equipment and spacecraft are received at the SXTF site until the equipment is shipped back to the plant.

Under the requirement to collect data from 70 measurement points using 20 data links, a minimum of four shots would be needed to sample each point at least once. Figure 25 shows the actions and times estimated to perform a 4-shot sequence. The following description of the expected test sequence specifies one good-quality PRS/MBS exposure for each test point. If two or possibly three good-quality results are wanted for statistical or data variation analysis, appropriate time to prepare and fire the combined PRS/MBS source should be added to the example sequence schedule. As indicated later, the close-in MBS-only sequence provides five data samples for each test point.

5.3.3 Combined PRS/MBS Test Sequence

Based on assumptions and time estimates for performing spacecraft operational tasks such as commanding the spacecraft to full power, recharging batteries, etc., and an estimate of reasonable test operations activities in executing each x-ray exposure, a step-by-step test sequence is described (see Figure 25). Because a number of activities associated with performing a test are done in parallel, many of which must be coordinated, the test sequence chart shows simultaneous steps taken by the satellite manufacturer (Ref. 8), the data acquisition group, the facility and test operations controller, and the photon source operators.

The rate at which x-ray exposures occur can be paced by one of two factors: either the minimum time between pulses from the sources or the time needed after each

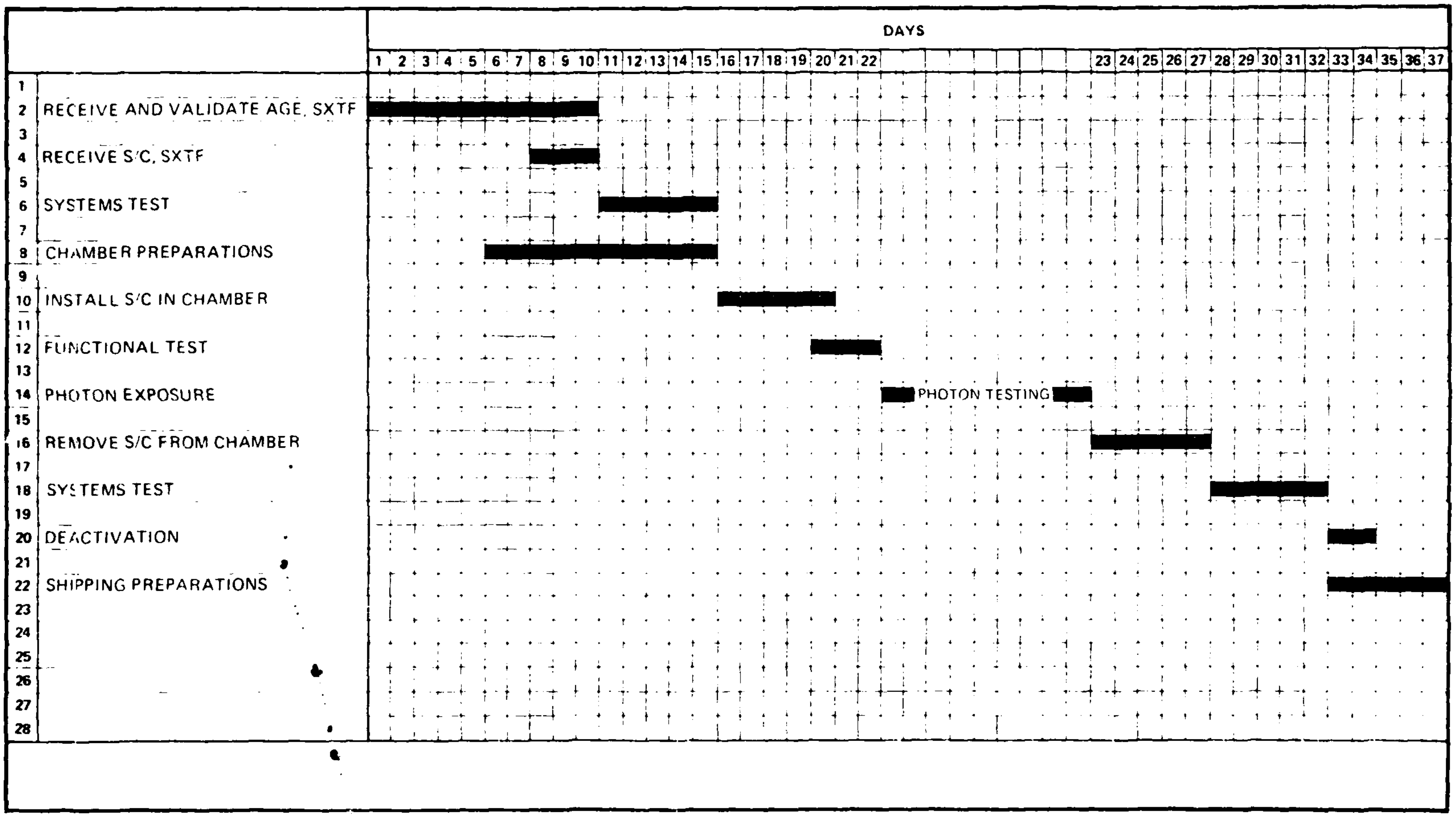


Figure 24. SXTF test schedule (from Ref. 8)

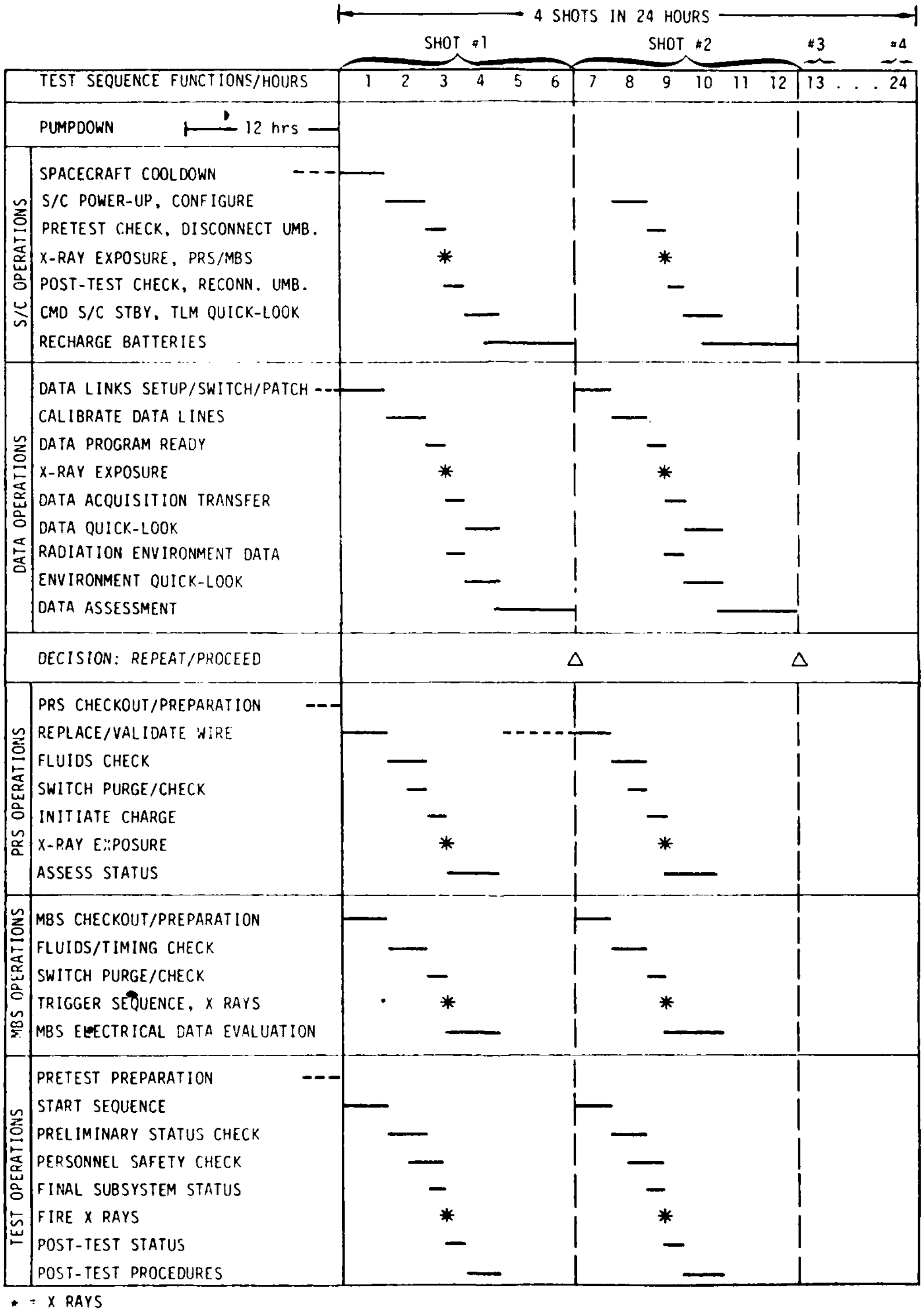


Figure 25. Combined MBS/PRS sequence

shot to evaluate data will determine how soon the next shot can be executed. The rate at which the machines can be turned around to be fired and the need to create the proper space environment, such as thermal stability or electron plasma charging, would pace the tests if the actual data-taking and analysis were done rapidly. If data acquisition and subsequent evaluation and interpretation of that data take longer than the time needed to prepare and operate the x-ray source and space test environment, the user becomes the pacing factor.

The importance of a test and the complexity or quantity of test measurements may require a fairly comprehensive and intensive assessment of data from each x-ray exposure. If the kind of data needed by the user can be processed and provided from pre-programmed algorithms constituting on-call software, the output from a 20-channel digitizer system could probably be made available to the user analysts in less than an hour. The illustrative test program shows quick-look data starting to be available for assessment in less than 1/2 hour after the shot. A 2-hour period is shown for assessment of the quality and sufficiency of the test before a decision is made to either repeat the shot or go on to the next sequence.

The schedule of Figure 25 indicates a 24-hour period to execute four combined MBS/PRS x-ray exposures, and includes expected pretest preparations and post-test analysis of results.

It is probably unrealistic to expect that this first two-shot sequence could be immediately followed by another two-shot sequence needed to gather all 70 data points. Experience has indicated that it is highly likely some problem in instrumentation, spacecraft support equipment, or x-ray source operation or some human error would prevent a straight-through sequence involving these interdependent subsystems. The sequence of four shots described here also assumes that no functional checks of the test object are performed between shots and that, therefore, no "holds" or temporary delays occur in performing any of the many preparatory tasks not detailed in these example test programs. There are many reasons why a test of this complexity may have to be either repeated or modified. Pre-fires of the sources would require, as a minimum, a restart of the test sequence. Calibration errors or incorrect estimates in expected signal levels could make test data unusable. Noise on test data is an ever-present hazard which requires repetition of the x-ray exposure after attempts are made to identify and correct the noise source.

Once all test data is acquired, recorded, processed, displayed, and analyzed, it [illegible] compared with previously established criteria for its validity and acceptability in satisfying the test objectives. Unless all test results match pretest estimates, time is often needed to deliberate on the advisability of repeating the test or going on to the next sequence.

A totally success-oriented test planner might schedule an immediate move into the next phase of testing. For this example test program, that would entail rotating the test object 90° before beginning another sequence of four x-ray exposures. Although it is possible to perform the rotation of the spacecraft remotely and to immediately proceed with the end-on test sequence, it appears prudent to allow the spacecraft manufacturer to do a system functional test either at this juncture or, as a minimum, at the next phase of the test, which would place the test object at the close-in position for MBS center body exposure. The decision on when and how many spacecraft functional tests are to be performed would probably be made based on results of spacecraft telemetry data. A functional spacecraft checkout would require chamber repressurization, spacecraft test equipment setup, the system functional test, and the reclosure and repumping of the vacuum vessel. An estimated time to perform this task is three days (72 hours).

For this illustrative test plan, the end-on test of four shots is assumed to have a schedule and sequence similar to the initial broadside test. It would take a minimum of 24 hours, as did the first four broadside shots. No system test is performed between the broadside and end-on sequences.

5.3.4 MBS-Only Close-In Tests

A schedule for the close-in MBS-only exposure sequence of 20 shots for the top and 20 shots for the bottom of the spacecraft center body is shown in Figure 26.

For the MBS-only operation, a total of 40 MBS shots is scheduled, 20 shots in each of two orientations. The test would be in five-shot sequences, each of which would gather data from the same group of sensors. After each rapid, 30-minute, five-shot sequence, results would be evaluated; if the results were satisfactory, the data links would be switched to a different set of the 70 total test points and another five-shot sequence begun. Four five-shot sequences would be required to obtain five samples from each of 70 test points, using the 20 fiber optic links, switchable to any of four inputs. A few of these points may not be pertinent to the close-in MBS center body test, but the switching arrangement would be the same as used on the previous whole-body test phase.

As illustrated in the schedule for close-in testing (Figure 26), each five-shot sequence takes about 6 hours from start of test sequence through the analysis and

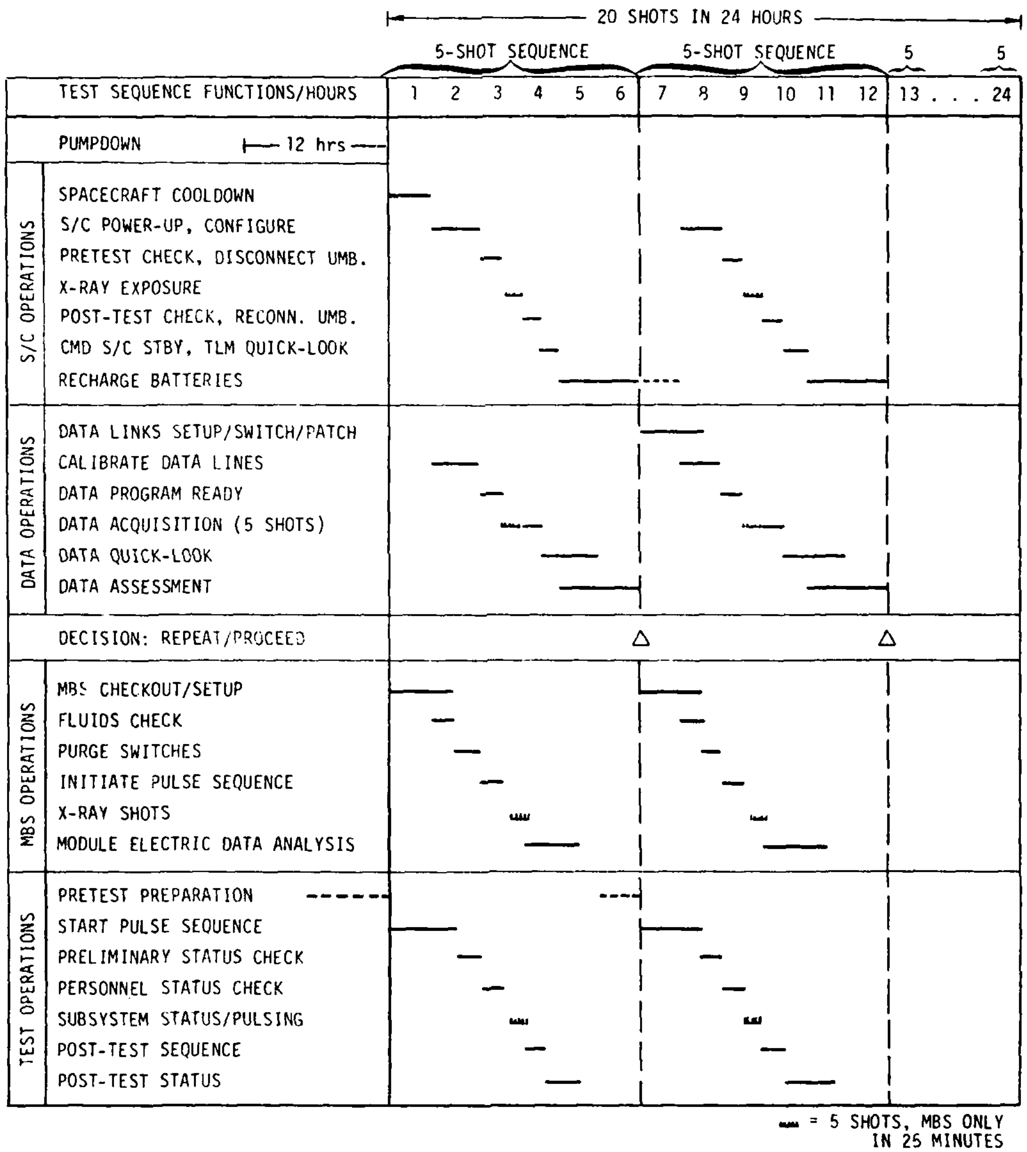


Figure 26. MBS-only test sequence

"continue on" decision. The top orientation sequence of 20 shots could be completed in one 24-hour period, assuming no "glitches." Again, depending on telemetry information and the manufacturer's philosophy on the need to confirm the operational status of the spacecraft, a spacecraft system functional test might be performed before the 20-shot sequence of close-in exposures are directed toward the bottom of the test object. If, as suggested in Reference 8, particular attention is to be paid to the active response of the spacecraft during these last 20 exposures, it is quite likely that some additional time may be needed by the manufacturer to evaluate his telemetry data, although spacecraft operational data would probably be analyzed in parallel with the EM data and may not add to the time needed to decide whether to proceed with the next group of five shots.

5.3.5 Illustrative Qual Test Schedule

A summary schedule is shown in Figure 27. It assumes that two spacecraft functional tests are performed during the photon exposure test period -- one between the MBS/PRS tests and the MBS-only tests, and one before the MBS-only, satellite-bottom, active-response test. This minimum spacecraft qualification test would take a total of about two months to perform a two-week x-ray exposure sequence consisting of eight PRS/MBS shots and 40 MBS-only shots.

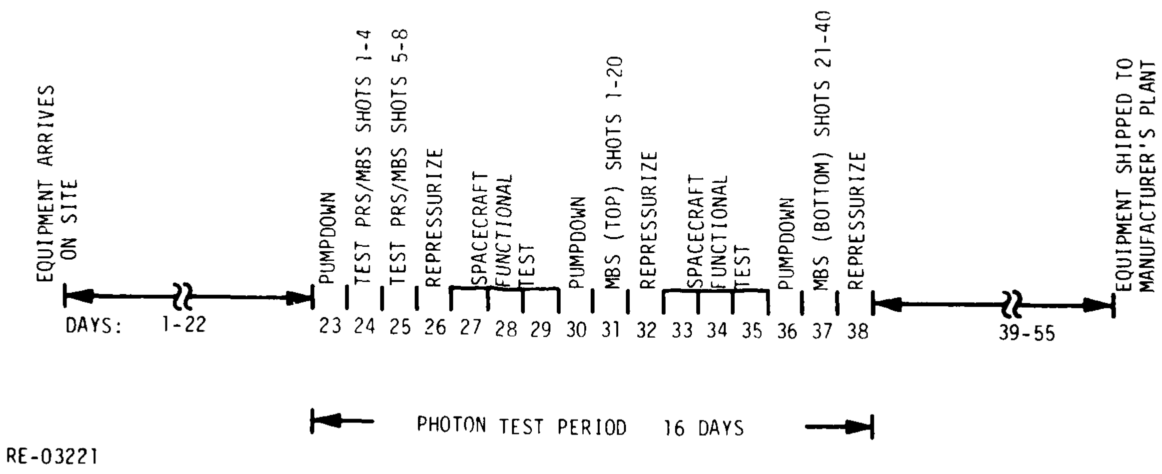


Figure 27. Sixteen-day test period of 2-month qualification test

5.4 SXTF STAFFING

The staff needed to perform SXTF operations at AEDC or NASA will be comprised of existing host facility personnel who will operate the space chamber and who will be trained to perform some additional functions associated with SXTF operations. In addition, new staff members will be added to perform special functions related to x-ray testing and operation/maintenance of new equipment.

Present staff at both candidate sites perform work in three functional areas: (1) test engineering, (2) facility operations, and (3) data acquisition. The following additional staff is envisioned as being needed to complement existing staff for SXTF tests.

A photon source operation/maintenance crew will initially be provided by the selected source manufacturer. Support from existing staff in the form of basic mechanical and electrical skills is expected. In addition, some existing technicians will be assigned added duties and trained on the job as PRS/MBS operations/maintenance technicians. After a transition and checkout period, estimated to be from one to two years, additional staff will be added to the host facility to perform all source operations/ maintenance functions.

The existing staff will continue to operate the space chamber vacuum and refrigeration equipment. It is expected that these technicians could also handle new tank internals such as the electron plasma sources, since existing staff presently perform solar illumination functions probably not needed for SXTF tests.

Two other functional areas will probably require augmentation of existing staff due to the addition of SXTF capability. The new data subsystem provided as part of the SXTF equipment will require new positions relating to dosimetry and SGEMP sensors and x-ray response data analysis support. The existing professional staff will require a nuclear weapons effect specialist who will act as the overall test coordinator on SXTF programs, and there will be a need for a pulse-power engineer to sustain and upgrade the x-ray source capability of the facility. One option for providing these professional skills would be for DNA to supply qualified individuals from the agency to the host site.

Most administrative, supply, and logistics functions could be handled by the host site staff. It might be appropriate to add a new administrative position to handle security and safety, particularly at NASA, where no classified or physical security control function now exists.

An illustrative staff organization chart for SXTF operations is shown in Figure 28. New staff functions are identified in heavy outline. Existing functional skills typical of the candidate site vacuum chamber operators are shown as shaded areas.

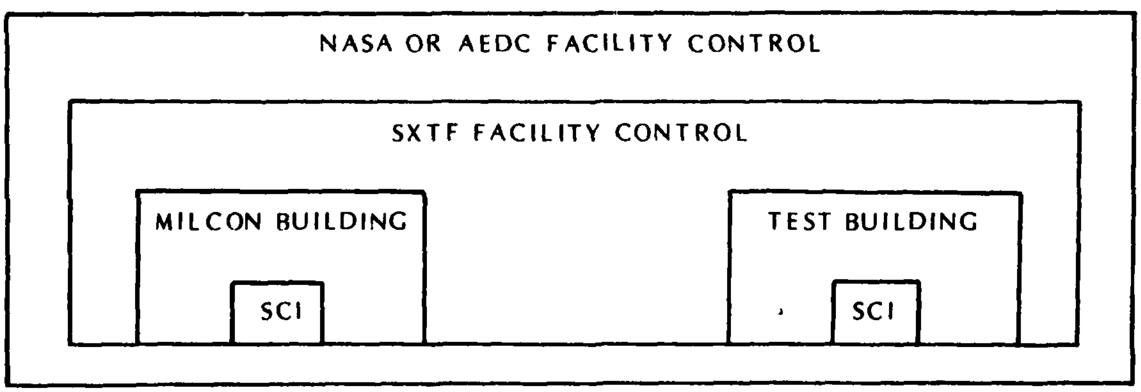
5.5 PHYSICAL SECURITY AND RADIATION PROTECTION CONCEPTS

Access control of the personnel at the SXTF includes two requirements: physical security of equipment and information of a classified nature, and protection of personnel against the effects of ionizing radiation created by the x-ray environment simulators. Both of these requirements basically entail identification and control of people and their access to specified areas.

5.5.1 Security Concept

The basic guide to physical security is DIA Manual 50-3. Previous development and coordination with DIA for the security plan for the SXTF reference design (Ref. 1) indicated that a security plan which included a number of controlled perimeters, one inside the next, was a preferred approach.

Implementing such an approach at an existing facility is more difficult but appears feasible at both AEDC and NASA. Such an approach requires an outer perimeter fence which would encompass the test building and the MILCON structure. Access inside this first perimeter would be controlled at preferably one location. Under the present plan to have a separate MILCON building, it appears desirable to have a capability for high-level security areas in both the MILCON and the test buildings. Access control to each structure and special controls within these structures, which might contain sensitive compartmented information (SCI), would have to be implemented. The sketch below shows the general multi-perimeter approach.



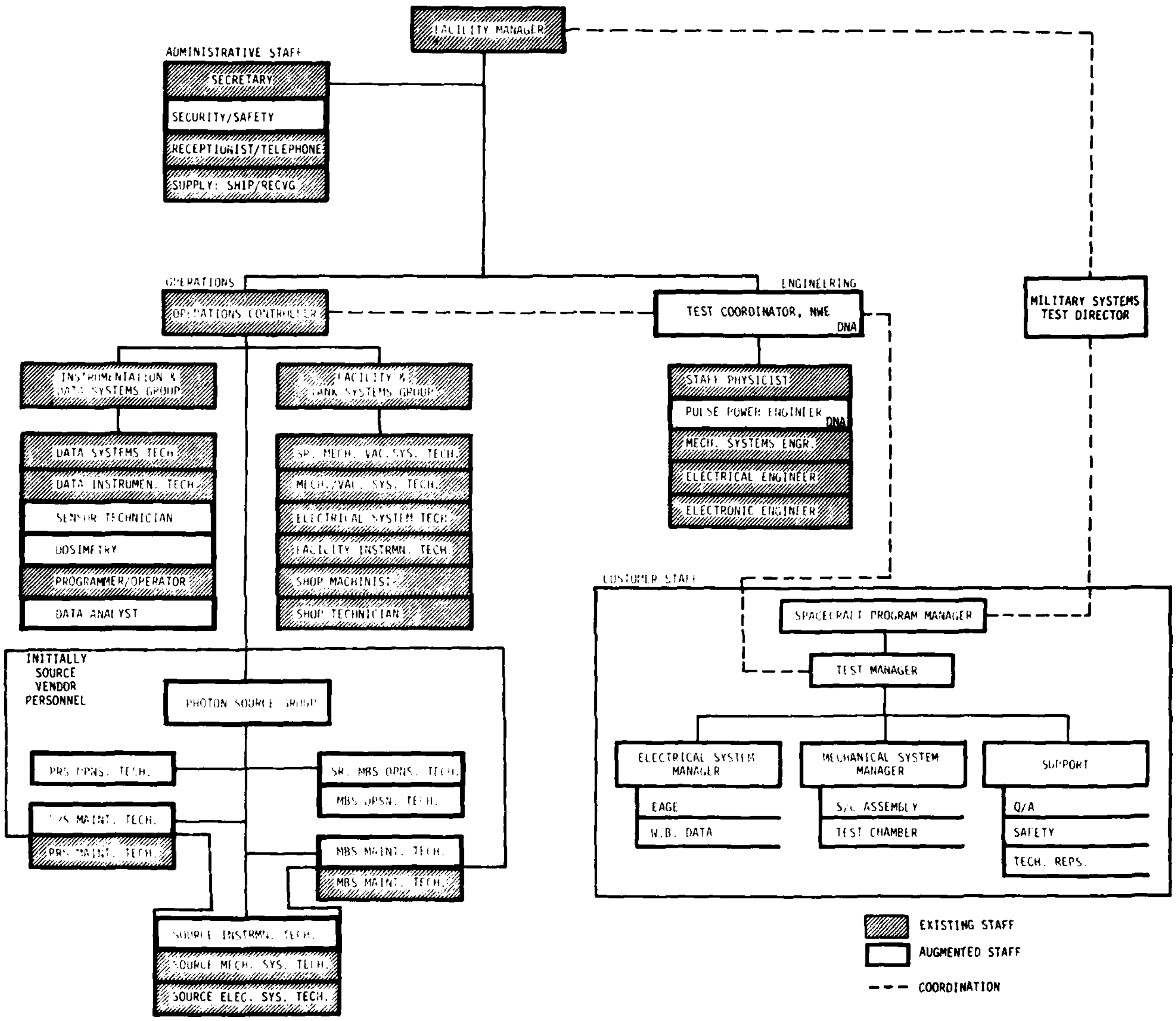


Figure 28. Representative SXTF staff organization and customer interface

5.5.2 AEDC Physical Security Concept

Physical security would be totally controlled at the SXTF MILCON building. At the RDT&E test building (Mark I), there are two physical security requirements:

1. Controlled access and security of the test object and related classified spacecraft equipment.
2. Control and security of the x-ray response data.

The basic approach will be to control all personnel access to the area around the test chamber, the satellite assembly area, the satellite EAGE, and the SXTF control and data rooms.

The following options appear feasible, depending on the capability and reasonability of security badging of all personnel in the Mark I facility.

1. If all personnel, AEDC and SXTF, can be badged, a total access control method can be initiated at the entrance to the Mark I facility, using key-lock doors or magnetic-card-controlled doors, all other doors being limited to emergency exit only.
2. If all personnel cannot be badged and only all SXTF-related personnel can be controlled, the following areas of the Mark I facility will have to be controlled, possibly requiring some additional secured doors or barrier partitions.
   - Satellite assembly area.
   - The high-bay containing the vacuum vessel.
   - The SXTF control and data rooms.

All initial security control and identification would be performed at the SXTF security center located in the MILCON building. The outermost perimeter would be the present controlled access to the AEDC facility at the main gate. The SXTF security perimeter would be the single controlled entrance to the perimeter fence encompassing the MILCON and test buildings (Mark I).

5.5.3 NASA Physical Security Concept

The physical security requirements at NASA are also based on the need to control access to possible classified satellites and to resultant survivability data from the tests. The unique isolation of the control and data rooms at NASA, because of the location of these spaces on the suspended floor at the 46-foot level, limits the accessibility of this area and simplifies implementation of security control to the data areas. Since these rooms are structurally stacked on three successive floors, all of which are entered from one of two stairwells or by the elevator, controlling access to the entry points will be the basic physical security method. Since the building in which both the "A" and "B" chambers are located and the large high-bay between them may not be easily secured, it may be necessary to establish rather arbitrary bounds to the secure area around the SXTF test chamber. The vessel itself would be the basic security perimeter for controlling satellite security. During periods when the chamber would have to be open, such as spacecraft entry and removal periods, the high-bay would have to be cleared of unbadged personnel and access controlled either by locking and monitoring all entrances or by use of temporarily manned guard stations.

In keeping with the general security approach of multiple perimeters, it may be necessary to provide a security fence around the perimeter of Bldg. 32 and any new MILCON structure located nearby. This requirement will be evaluated in more detail. It would be desirable to eliminate a security fence around Bldg. 32 since it is recognized that the NASA facilities are not normally secured. If the spacecraft can be properly secured by controlled access to the vacuum vessel itself, and if multiple perimeters can be established within the RDT&E high-bay structure, providing sufficient security to classified areas, a perimeter fence around the facility may not be required.

If the spacecraft itself is not classified and if the primary security requirement is for security of test data, the only high-level security space within Bldg. 32 would be the SXTF data subsystem control room. Data analysis and data storage could be provided in high-level security space in the MILCON building, which would be separate and fully secure and could have a separate perimeter fence.

5.5.4 Radiation Safety Analysis

The AEDC Mark I and the NASA "A" chamber will utilize a number of high-power pulse machines which can produce ionizing radiation in the form of x-ray pulses plus electron sources for spacecraft charging. The amount of radiation created by the SXTF is determined by two factors: the energy per pulse or exposure event, and the number of such events.

Three radiation sources are under consideration:

1. The MBS, an array of some 200 modules which produce x rays by the bremsstrahlung process of decelerating electrons, presently specified

to operate at up to 200 kV and create an x-ray pulse of <1 μsec in duration.

2. The PRS, a single high-energy pulse machine that creates an ionized plasma and generates a short-duration, low-energy x-ray spectrum; of particular concern is a theoretically possible PRS misfire mode in which the energy of the source is converted into high-energy electrons, producing a very "hard" x-ray environment.
3. Electron-beam sources, which charge the test object using electrons with energies up to 300 kV.

An analysis of the radiation problem for the SXTF, performed early in the program (1977), considered only the soft PRS x-ray energy and the MBS operating at 100 kV. For these conditions, it appeared that the vacuum vessel itself would provide adequate protection from radiation hazards outside the test chamber. Thereafter, the situation was complicated by four factors:

- Consideration of the PRS misfire mode.
- Consideration of MBS operations at high voltage (~200-keV diode voltage).
- Requirement for a capability to investigate spacecraft charging due to high-energy electrons.
- Reduction in the personnel radiation doses allowed for occupational workers and the general public.

Considering the radiation exposure standards presently published (1.25 rem per quarter for professionals and 1/10 that value for the general public), little change appeared to be required in the SXTF design to take care of the first three factors listed above. Therefore, the conceptual design for an SXTF at Vandenberg AFB included only a concrete shielding wall between the vacuum vessel and the MILCON building in which operational personnel would be located.

The fourth factor, reductions in the allowable radiation levels, necessitates considerably more protection. It appears that radiation levels produced by man may be limited to values approaching the ambient natural levels or less. Recent published guidance reduces the allowable doses to 50 mrem/quarter for professionals and 25 mrem/year for the general workers, and as low as 5 mrem/year for the public. These developments have forced a basic reconsideration of the entire radiation protection problem. It now appears that additional concrete, steel, or lead sheeting on portions of the outside of the tank will be necessary. Further, the high-energy electron sources will have to be placed to irradiate the exposure body from selected directions to minimize the effects of scattered radiation.

Two very subjective factors affect the dose levels calculated for the SXTF. One of these is the nature of the PRS misfire mode, which can occur if there is no material at the terminal end of the PRS pulse line (open circuit). Such a condition could result in an appreciable amount of electrical energy being converted into high-velocity electrons. The photon yield from a PRS misfire is quite uncertain; in this analysis, we use a DNA estimate of 80 kJ in the form of 2.5-MeV electrons. The second subjective factor is the estimate of the number of x-ray exposures and chargings with high-energy electrons that could occur in one calendar quarter or during one year.

For a facility totally dedicated to x-ray testing, as is the case of the SXTF reference design, the calculations use upper limits of equipment capability and long-term test programs. The radiation calculations, involving the modification and joint use of either the AEDC Mark I chamber or the NASA "A" chamber, use a revised set of operational conditions. These values reflect the judgment that x-ray testing would not occur continuously throughout a calendar year, and that operational constraints will limit the number of x-ray exposures any particular test program will be able to perform.

The following parameters for radiation analysis were used.

MBS, 200 Modules

250 shots/quarter at 200 kV operation, 50 J per module

250 shots/quarter at 100 kV operation, 25 J per module

PRS

One time/year misfire mode, 80-kJ energy in the form of 2.5-MeV electrons

Electron Beams

25 chargings/quarter of 300-keV electrons at 5×10^{12} e/cm^2 over 6×14 m target area. The value of 5×10^{12} e/cm^2 is an upper-limit estimate of the surface charge density required to produce electrostatic discharges in typical satellite dielectrics and cables.

The radiation dose criterion for this analysis is based on 50 mrem/quarter for industrial personnel and 25 mrem/year for the on-site general public. The three sources of ionizing radiation at the SXTF have been evaluated and will produce radiation dose levels above those acceptable to the general public in certain areas near the test building and, using the present shielding concept (~0.635 m of lead on the tank), will produce exposure levels above the industrial design level at certain places close to the sources.

The potential radiation exposure levels for the three sources are different in their characteristics in that the MBS and E-beam sources create low-level, one-time exposures, but since many shots can be expected over a period of time, the total possible radiation dose can exceed the general public level in some areas near the sources. Therefore, the area immediately around the vacuum vessel (the high-bay in which it is contained) must be designated a limited-access area during MBS or E-beam operations and must be an excluded area when the PRS is operated.

To control general public exposure to radiation from any of the sources, a safety line ~100 ft (31 m) from the sources, in the direction in which the sources radiate into the vacuum vessel, must be established.

The general radiation protection requirements can be categorized by the following access control areas.

1. Uncontrolled or general public areas in which radiation exposure is less than the specified general public exposure level of 25 mrem/year.
2. Industrial exposure areas in which the exposure level for accumulated dose is below 50 mrem/quarter or the one-time exposure is less than 200 mrem/year. These areas require badged and trained personnel and radiation level monitors.
3. Excluded areas in which possible exposure levels exceed the industrial level. Some areas may be limited-access, such as hallways or open spaces which personnel do not permanently occupy and in which only accumulated dose from MBS or E-beam operations could reach industrial levels.

5.5.5 Radiation Protection at AEDC and NASA

The radiation control areas for AEDC and NASA are shown in Figures 29 and 30. These area boundaries were developed from a preliminary radiation threat analysis (Ref. 9). A final radiation analysis for the selected SXTF site will refine these areas. A more clear definition of allowable radiation levels and evaluation of safety margins in the

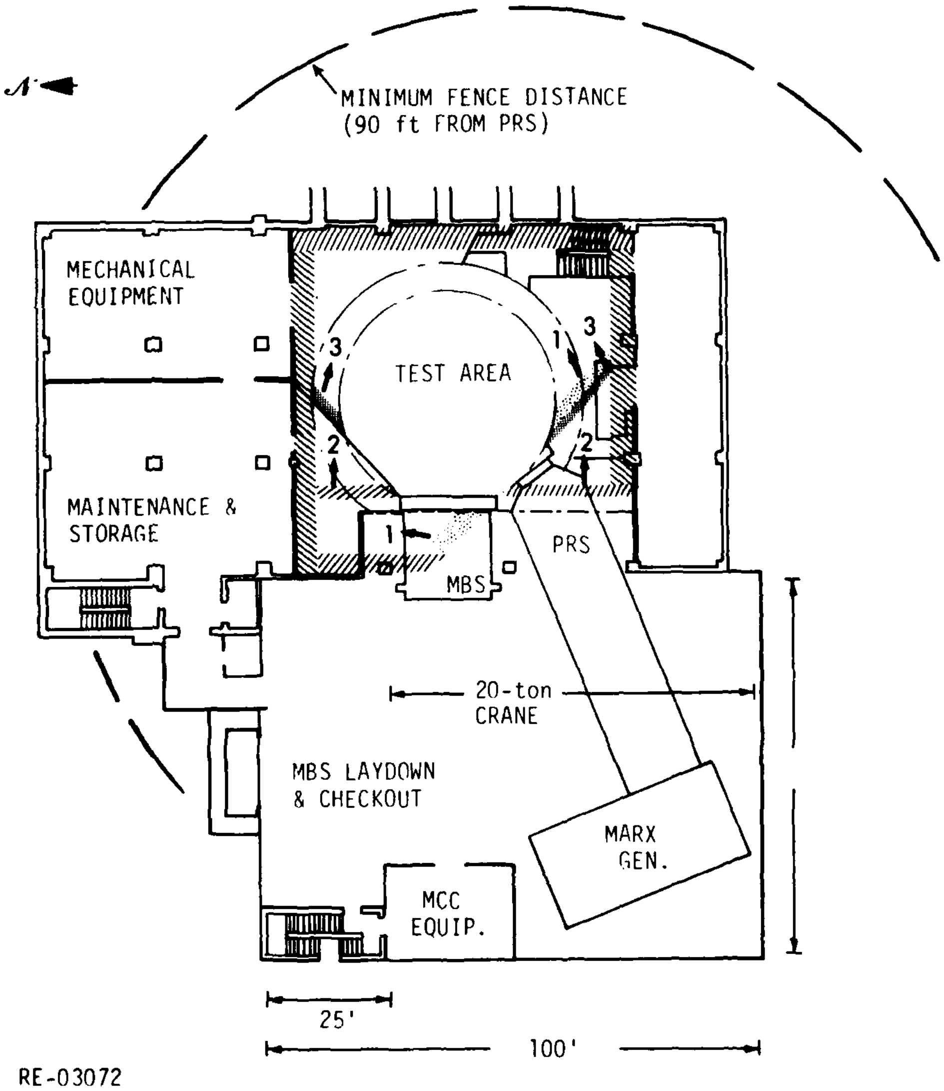


Figure 29. Excluded and limited-access areas for AEDC Mark I tank (1-1, excluded area during PRS testing; 2-2, limited-access area during MBS testing with no MBS collimation; 3-3, limited-access area during MBS testing with 45° MBS collimation)

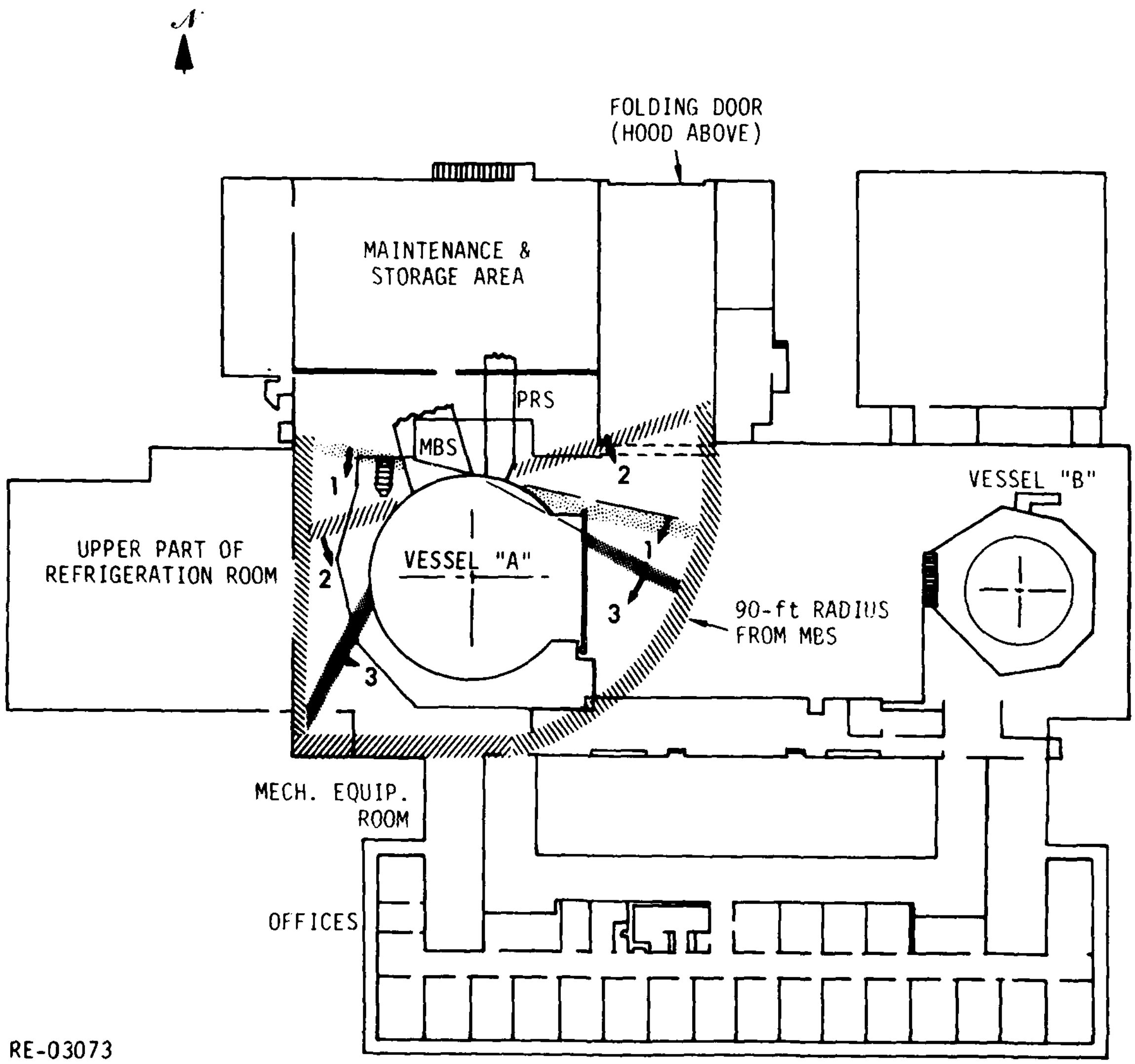


Figure 30. Excluded and limited-access areas for NASA "A" chamber (1-1, excluded area during PRS testing; 2-2, limited-access area during MBS testing with no MBS collimation; 3-3, limited-access area during MBS testing with 45° MBS collimation)

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preliminary analysis may modify these areas. There appears to be considerable conservatism in the preliminary calculations.

For the AEDC tank, industrial radiation design values can be achieved immediately outside the tank building using slightly more than 0.1 inch (0.254 cm) of lead over the tank area that is illuminated by the MBS, PRS, and high-energy electrons. A fence is required about 90 feet from the sources to keep the public at a distance where nonindustrial design values can be achieved. For the NASA tank, between 0.1 and 0.25 (0.254-0.635 cm) inch of lead is required over the tank area that is illuminated by the MBS, PRS, and high-energy electrons to achieve the nonindustrial design values immediately outside the tank building. For both sites, the space immediately around the tank forward of the PRS tangency line must be off-limits to all personnel during PRS tests. In addition, the space immediately around the tank forward of the MBS and the high-energy electron sources must be limited-access areas during those kinds of radiation tests.

6. SXTF PROGRAM SCHEDULE

An illustrative schedule for SXTF modification for either AEDC or NASA is shown in Figure 31. The schedule represents estimates of major milestones, design, and construction tasks for engineering and modifying either of these two existing facilities. A revised schedule will be developed by the A& E during completion of the final procurement package to be prepared in 1981.

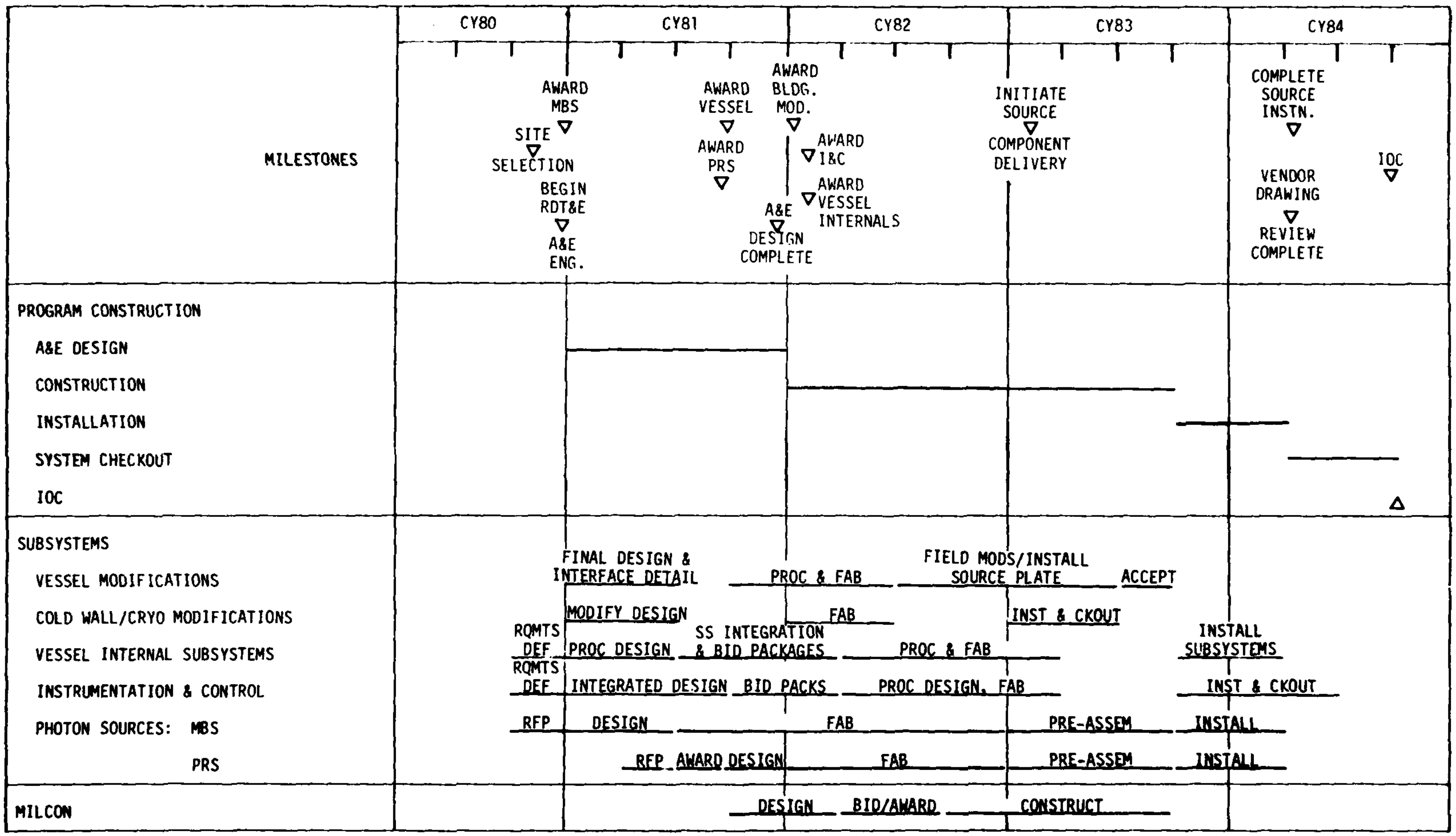

Figure 31. Illustrative schedule for modifying AEDC or NASA for SXTF capability

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GLOSSARY OF ABBREVIATIONS

Å	Angstrom (10^{-10} m, wavelength)
A&E	Architect and engineer
AC	Alternating current
A-D	Analog-to-digital
AEDC	Arnold Engineering Development Center
AGE	Aerospace ground equipment
AVCS	Altitude-velocity control system
CRT	Cathode ray tube
DIA	Defense Intelligence Agency
DNA	Defense Nuclear Agency
DP	Diffusion pump or data processing
DSCS	Defense satellite communication system
EAGE	Electronic aerospace ground equipment
ECEMP	Electron-caused electromagnetic pulse
EM	Electromagnetic
FLTSATCOM	Fleet satellite communications
FO	Fiber optics
FY	Fiscal year (government, October-October)
IOC	Initial operational capability
J	Joule (energy)
keV	Thousand electron volts
kV	Thousand volts
LN_2	Liquid nitrogen
MB	Megabit
MBS	Modular bremsstrahlung source
MeV	Million electron volts
MILCON	Military construction
MLI	Maxwell Laboratories, Inc.
MRC	Mission Research Corp.
mrem	1/1000 rem
MTBF	Mean time between failures
MUX	Multiplex equipment

MUX	Multiplex equipment
nA	10^{-9} amp
NASA	National Aeronautics and Space Agency
NEC	Norman Engineering Company
nsec	10^{-9} sec
PI	Physics International
PRS	Plasma radiating source
RDT&E	Research, development, test and evaluation
rem	Roentgen equivalent, man
RFP	Request for proposal
SAMSO	Space and Missile Systems Organization (now Space Division, Systems Command)
S/C	Spacecraft
SGEMP	System-generated electromagnetic pulse
SXTF	Satellite x-ray test facility
torr	1 torr = 1 mm Hg (atmospheric pressure)
TREE	Transient radiation effects on electronics
TT&C	Telemetry, tracking and control
UGT	Underground test
UV	Ultraviolet light
Z	Atomic number

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